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PRINCIPAL CONTENTS.

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MENA, JUAN DE, one of the Italianizing Spanish poets of the 15th century, was born at Cordova about 1411. We are informed by Romero, to whom we are indebted for almost all we know about his life, that he had ıttained the age of twenty-three before he began to give himself to "the sweet labour of good learning," pursuing a regular course of study at Salamanca and afterwards at Rome. It was at the latter city that he first became ıcquainted with the writings of Dante and Petrarch, which ıfterwards so powerfully influenced his own style. Having returned to Spain, he became a "veinticuatro," or magis-rate, of his native town, and was received as a poet with great favour at the court of John II., being made Latin secre-ary to the king and historiographer of Castile. He died uddenly, in consequence of a fall from his mule, in 1456, ıt Torrelaguna, where the marquis of Santillana, his friend ınd patron, erected his monument and wrote his epitaph. De Mena's principal work, *El Laberinto* ("The Labyrinth"), ometimes called *Las Trescientas* ("The Three Hundred") rom the original number of its stanzas, is a didactic llegory on the duties and destinies of man, obviously con-tructed on the lines of the *Divina Commedia* of Dante. The poet, while wandering in a wood and exposed to the ıttacks of various beasts of prey, is met by Providence in he guise of a beautiful woman, who offers to guide him afely through the dangers which surround him, and at the ame time to explain—"as far as they may be grasped by uman understanding"—the dark mysteries of life that veigh upon his spirit. He is then led to the spherical entre of the five zones, where he sees the three wheels of estiny, the past, the future, and the present, and the men elonging to each, arranged in the seven circles of planetary nfluence. Opportunity is thus afforded for a vast quan-ity of mythological and historical portraiture; the best ketches are those of the poet's own contemporaries, but he work in general is much disfigured with all sorts of edantry, and hardly ever attains to mediocrity as a poem. The *Laberinto* was first printed at Seville in 1496; Nuñez nd Sanchez accompanied it with commentaries in 1499 nd 1582 respectively; and it is still regarded with a good eal of reverence by the Spaniards as the "magnum opus" f their "Ennius." De Mena was the author of a number f minor poems or "vers de société," written merely for court circles, and having neither general interest nor per-manent value; most of them are to be found in the *Cancionero General*. He also wrote a poem entitled *La Coronacion*, the subject being the "crowning" of the marquis of Santillana by the Muses and the Virtues on Mount Parnassus. Finally, his *Siete Pecados Mortales* ("Seven Deadly Sins") is a dull allegory on the antagonism between reason and the will of man. Complete editions of the poems of De Mena appeared in 1528, 1804, and 1840.

MÉNAGE, GILLES (1613-1692), described by Bayle as "one of the most learned men of his time, and the Varro of the 17th century," was the son of Guillaume Ménage, king's advocate at Angers, and was born in that city on August 15, 1613. A tenacious memory and an early developed enthusiasm for learning carried him speedily through his literary and professional studies, and we read of him practising at the bar at Angers as early as 1632. In the same year he pleaded several causes before the parlement of Paris, and soon afterwards he attended the "Grand Tours" at Poitiers, but after having been laid aside by a severe illness he abandoned the legal profession and declared his intention of entering the church. He succeeded in obtaining some sinecure benefices, and lived for some years in the household of Cardinal De Retz (then only coadjutor to the archbishop of Paris), where he had ample leisure for his favourite literary pursuits. Some time after 1648 he withdrew to a house of his own in the cloister of Notre Dame, where his remarkable conversational powers enabled him to gather round him on Wednesday evenings those much frequented literary assemblies which he called "Mercuriales." His learning procured for him admission to the Della Cruscan Academy of Florence, but his irrepressible tendency to caustic sarcasm led to his remorseless exclusion from the French Academy. He died at Paris on July 23, 1692. Of the voluminous works of Ménage (fully enumerated in the *Dictionnaire* of Chauffepié) the following may be mentioned:—*Origines de la Langue Françoise* (1650; greatly enlarged in 1694); *Diogenes Laertius Græce et Latine, cum Commentario* (1663, and again much improved in 1692); *Poemata Latina, Gallica, Græca, et Italica* (1656; 8th ed., 1687); *Origini della Lingua Italiana* (1669); and *Anti-Baillet* (1690).

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In all, we have, as collected by Meineke, 1045 fragments of Menander, of which 515 can be referred to known plays, the titles of those quoted from amounting to ninety, and including the Terentian *Andria, Adelphi, Eunuchus, Heautontimorumenos*. These fragments contain about 1650 verses or parts of verses, not including a considerable number of words quoted expressly as from Menander by the old lexicographers. Besides all these there are not fewer than 758 monostich verses separately preserved in MSS., though some of these are met with in the other and longer fragments. Many of the fragments are obscure, some corrupt; and they have been a fertile field for critical acumen from the time of Bentley. Not unfrequently we come upon the shrewd or original remark of an observer. Thus (frag. 7) "A poor man has no relations, for no one acknowledges him, lest he should beg." Frag. 145, "Everything that takes place is brought about by law, necessity, or fashion." 237, "The gods do not save men through any human means (prayer or sacrifices); if they did, the human would have more power than the divine." 275, "Poverty is the most easily cured of all evils; any friend can do it by merely putting his hand in his pocket." 397, "A poor man who lives in a large town makes himself more wretched than he need; for he cannot help comparing with his own the luxurious lives of the rich." 435, "No man realizes the extent of a sin when he commits it; it is afterwards that he sees it." 460, "A man is convinced not so much by what is said as by the manner of saying it." 474, "There is one thing only that hides vulgarity, villainy, and every other fault,—wealth. Everything but that is carped at and criticized." 517, "People who have no merit of their own generally boast of their birth and their ancestors. But every living man has ancestors, or he would not be a living man." 578, "Wealth acts on a man as wind does on a ship,—it often forces him out of his proper course." 663, "Many a young lady says a great deal in her own favour by saying nothing at all." 688, "A man who abuses his own father is practising blasphemy against the gods." In fact, Menander is characteristically a sententious writer, like Euripides, with whom in the general style of his writings, though not, of course, in his somewhat loose and irregular versification, he is sometimes compared. (F. A. P.)

MENCIUS, the Latinized form of Măng-tsze, "Mr Măng," or "Măng the philosopher," a name in China only second as a moral teacher to that of Confucius. His statue or spirit-tablet (as the case may be) has occupied, in the temples of the sage, since our 11th century, a place among "the four assessors"; and since 1530 A.D. his title has been "the philosopher Măng, sage of the second degree."

The Măngs or Măng-suns had been in the time of Confucius one of the three great clans of Lû (all descended from the marquis Hwan, 711–694 B.C.), which he had endeavoured to curb. Their power had subsequently been broken, and the branch to which Mencius belonged had settled in Tsâu, a small adjacent principality, the name of which still remains in Tsâu hsien, a district of Yenchâu Shan-tung. A magnificent temple to Mencius is the chief attraction of the district city. The present writer visited it in 1873, and was struck by a large marble statue of him in the courtyard in front. It shows much artistic skill, and gives the impression of a man strong in body and mind, thoughtful and fearless. His lineal representative lives in the city, and thousands of Măngs are to be found in the neighbourhood.

The dates of some of the principal events in Mencius's life are fixed by a combination of evidence, and his death is referred by common consent to the year 289 B.C. He had lived to a great age,—some say to his eighty-fourth year, placing his birth in 372 B.C., and others to his ninety-seventh, placing it in 385. All that we are told of his father is that he died in the third year of the child, who was thus left to the care of his mother. She was a lady of superior character, and well discharged her trust. Her virtues and dealings with her son were celebrated by a great writer in the first century before our era, and for two thousand years she has been the model mother of China.

[1] Mahaffy, *Ibid.*, p. 490.

We have no accounts of Mencius for many years after his boyhood, and he is more than forty years old when he comes before us as a public character. He must have spent much time in study, investigating the questions which were rife as to the fundamental principles of morals and society, and brooding over the condition of the country. The history, the poetry, the institutions, and the great men of the past had received his careful attention. He intimates that he had been in communication with men who had been disciples of Confucius. That sage had become to him the chief of mortal men, the object of his untiring admiration; and in the doctrines which he had taught Mencius recognized the truth for want of an appreciation of which the bonds of order all round him were being relaxed, and the kingdom hastening to a general anarchy.

When he first comes forth from Tsâu, he is accompanied by several eminent disciples. He had probably imitated Confucius in becoming the master of a school, and encouraging the resort to it of inquiring minds that he might resolve their doubts and unfold to them the right methods of government. One of his sayings is that it would be a greater delight to the superior man to get the youth of brightest promise around him and to teach and train them than to enjoy the revenues of the kingdom. His intercourse with his followers was not so intimate as that of Confucius had been with the members of his selected circle; and, while he maintained his dignity among them, he was not able to secure from them the same homage and reverent admiration.

More than a century had elapsed since the death of Confucius, and during that period the feudal kingdom of Châu had been showing more and more of the signs of dissolution, and portentous errors that threatened to upset all social order were widely disseminated. The sentiment of loyalty to the dynasty had disappeared. Several of the marquises and other feudal princes of earlier times had usurped the title of king. The smaller fiefs had been absorbed by the larger ones, or reduced to a state of helpless dependence on them. Tsin, after greatly extending its territory, had broken up into three powerful kingdoms, each about as large as England. Mencius found the nation nominally one, and with the traditions of two thousand years affirming its essential unity, but actually divided into seven monarchies, each seeking to subdue the others under itself. The consequences were constant warfare and chronic misery.

In Confucius's time we meet with recluses who had withdrawn in disgust from the world and its turmoil; but these had now given place to a class of men who came forth from their retirements provided with arts of war or schemes of policy which they recommended to the contending chiefs, ever ready to change their allegiance as they were moved by whim or interest. Mencius was once asked about two of them, "Are they not really great men? Let them be angry, and all the princes are afraid. Let them live quietly, and the flames of trouble are everywhere extinguished." He looked on them as little men, and delighted to proclaim his idea of the great man in such language as the following:—

"To dwell in love, the wide house of the world, to stand in propriety, the correct seat of the world, and to walk in righteousness, the great path of the world; when he obtains his desire for office, to practise his principles for the good of the people, and when that desire is disappointed, to practise them alone; to be above the power of riches and honours to make dissipated, of poverty and mean condition to make swerve from the right, and of power and force to make bend,—these characteristics constitute the great man."

Most vivid are the pictures which Mencius gives of the condition of the people in consequence of the wars of the states. "The royal ordinances were violated; the multi-

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[13] A curious example is ἀπεκτάγκασι, the transitive perfect of ἀποκτείνειν. Similarly we have the unusual forms κέχρηκα (frag. 559), ἐψόφηκα (727), συγκέχυκα (810).

(ἀποδοκιμάζειν) is ill-suited even to choral metre. The Old Comedy was worked by men of real genius, who "were indeed giants, while the men of Menander's day only showed how strong and thorough was the culture which in art and literature outlived the decadence of the nation."[1]

In all, we have, as collected by Meineke, 1045 fragments of Menander, of which 515 can be referred to known plays, the titles of those quoted from amounting to ninety, and including the Terentian *Andria, Adelphi, Eunuchus, Heautontimorumenos.* These fragments contain about 1650 verses or parts of verses, not including a considerable number of words quoted expressly as from Menander by the old lexicographers. Besides all these there are not fewer than 758 monostich verses separately preserved in MSS., though some of these are met with in the other and longer fragments. Many of the fragments are obscure, some corrupt; and they have been a fertile field for critical acumen from the time of Bentley. Not unfrequently we come upon the shrewd or original remark of an observer. Thus (frag. 7) "A poor man has no relations, for no one acknowledges him, lest he should beg." Frag. 145, "Everything that takes place is brought about by law, necessity, or fashion." 237, "The gods do not save men through any human means (prayer or sacrifices); if they did, the human would have more power than the divine." 275, "Poverty is the most easily cured of all evils; any friend can do it by merely putting his hand in his pocket." 397, "A poor man who lives in a large town makes himself more wretched than he need; for he cannot help comparing with his own the luxurious lives of the rich." 435, "No man realizes the extent of a sin when he commits it; it is afterwards that he sees it." 460, "A man is convinced not so much by what is said as by the manner of saying it." 474, "There is one thing only that hides vulgarity, villainy, and every other fault,—wealth. Everything but that is carped at and criticized." 517, "People who have no merit of their own generally boast of their birth and their ancestors. But every living man has ancestors, or he would not be a living man." 578, "Wealth acts on a man as wind does on a ship,—it often forces him out of his proper course." 663, "Many a young lady says a great deal in her own favour by saying nothing at all." 688, "A man who abuses his own father is practising blasphemy against the gods." In fact, Menander is characteristically a sententious writer, like Euripides, with whom in the general style of his writings, though not, of course, in his somewhat loose and irregular versification, he is sometimes compared. (F. A. P.)

MENCIUS, the Latinized form of Măng-tsze, "Mr Măng," or "Măng the philosopher," a name in China only second as a moral teacher to that of Confucius. His statue or spirit-tablet (as the case may be) has occupied, in the temples of the sage, since our 11th century, a place among "the four assessors"; and since 1530 A.D. his title has been "the philosopher Măng, sage of the second degree."

The Măngs or Măng-suns had been in the time of Confucius one of the three great clans of Lû (all descended from the marquis Hwan, 711–694 B.C.), which he had endeavoured to curb. Their power had subsequently been broken, and the branch to which Mencius belonged had settled in Tsâu, a small adjacent principality, the name of which still remains in Tsâu hsien, a district of Yenchâu Shan-tung. A magnificent temple to Mencius is the chief attraction of the district city. The present writer visited it in 1873, and was struck by a large marble statue of him in the courtyard in front. It shows much artistic skill, and gives the impression of a man strong in body and mind, thoughtful and fearless. His lineal representative lives in the city, and thousands of Măngs are to be found in the neighbourhood.

The dates of some of the principal events in Mencius's life are fixed by a combination of evidence, and his death is referred by common consent to the year 289 B.C. He had lived to a great age,—some say to his eighty-fourth year, placing his birth in 372 B.C., and others to his ninety-seventh, placing it in 385. All that we are told of his father is that he died in the third year of the child, who was thus left to the care of his mother. She was a lady of superior character, and well discharged her trust. Her virtues and dealings with her son were celebrated by a great writer in the first century before our era, and for two thousand years she has been the model mother of China.

[1] Mahaffy, *Ibid.*, p. 490.

We have no accounts of Mencius for many years afte his boyhood, and he is more than forty years old when h comes before us as a public character. He must have spen much time in study, investigating the questions which wer rife as to the fundamental principles of morals and society and brooding over the condition of the country. The his tory, the poetry, the institutions, and the great men of th past had received his careful attention. He intimates tha he had been in communication with men who had bee disciples of Confucius. That sage had become to him th chief of mortal men, the object of his untiring admiration and in the doctrines which he had taught Mencius recog nized the truth for want of an appreciation of which th bonds of order all round him were being relaxed, and th kingdom hastening to a general anarchy.

When he first comes forth from Tsâu, he is accompanie by several eminent disciples. He had probably imitate Confucius in becoming the master of a school, and en couraging the resort to it of inquiring minds that h might resolve their doubts and unfold to them the righ methods of government. One of his sayings is that i would be a greater delight to the superior man to get th youth of brightest promise around him and to teach an train them than to enjoy the revenues of the kingdom His intercourse with his followers was not so intimate a that of Confucius had been with the members of hi selected circle; and, while he maintained his dignity amon them, he was not able to secure from them the sam homage and reverent admiration.

More than a century had elapsed since the death o Confucius, and during that period the feudal kingdom o Châu had been showing more and more of the sign of dissolution, and portentous errors that threatened t upset all social order were widely disseminated. Th sentiment of loyalty to the dynasty had disappeared Several of the marquises and other feudal princes of earlie times had usurped the title of king. The smaller fiefs ha been absorbed by the larger ones, or reduced to a state o helpless dependence on them. Tsin, after greatly extend ing its territory, had broken up into three powerful king doms, each about as large as England. Mencius foun the nation nominally one, and with the traditions of tw thousand years affirming its essential unity, but actuall divided into seven monarchies, each seeking to subdue th others under itself. The consequences were constant war fare and chronic misery.

In Confucius's time we meet with recluses who ha withdrawn in disgust from the world and its turmoil; bu these had now given place to a class of men who cam forth from their retirements provided with arts of war o schemes of policy which they recommended to the contend ing chiefs, ever ready to change their allegiance as they were moved by whim or interest. Mencius was once aske about two of them, "Are they not really great men? Le them be angry, and all the princes are afraid. Let them live quietly, and the flames of trouble are everywhere ex tinguished." He looked on them as little men, an delighted to proclaim his idea of the great man in such language as the following:—

"To dwell in love, the wide house of the world, to stand i propriety, the correct seat of the world, and to walk in righteousness the great path of the world; when he obtains his desire for office, to practise his principles for the good of the people, and when tha desire is disappointed, to practise them alone; to be above th power of riches and honours to make dissipated, of poverty an mean condition to make swerve from the right, and of power an force to make bend,—these [illegible] constit[illegible] the grea man."

Most vivid are

tudes were oppressed; the supplies of food and drink flowed away like water." It is not wonderful that, when the foundations of government were thus overthrown, speculations should have arisen that threatened to overthrow what he considered to be the foundations of truth and all social order. "A shrill-tongued barbarian from the south," as Mencius called him, proclaimed the dissolution of ranks, and advocated a return to the primitive simplicity,

"When Adam delved and Eve span."

He and his followers maintained that learning was quackery, and statesmanship craft and oppression, that prince and peasant should be on the same level, and every man do everything for himself. Another, called Yang-chû, denied the difference between virtue and vice, glory and shame. The tyrants of the past, he said, were now but so many rotten bones, and the heroes and sages were no more. It was the same with all at death; after that there was but so much putridity and rottenness. The conclusion of the whole matter therefore was—"Let us eat and drink; let us gratify the ears and eyes, get servants and maidens, beauty, music, wine; when the day is insufficient, carry it on through the night. Each one for himself." Against a third heresiarch, of a very different stamp, Mencius felt no less indignation. This was Mo Tî, who found the source of all the evils of the time and of all time in the want of mutual love. He taught, therefore, that men should love others as themselves; princes, the states of other princes as much as their own; children, the parents of others as much as their own. Mo, in his gropings, had got hold of a noble principle, but he did not apprehend it distinctly nor set it forth with discrimination. To our philosopher the doctrine appeared contrary to the Confucian orthodoxy about the five relations of society; and he attacked it without mercy and with an equal confusion of thought. "Yang's principle," he said, "is 'each one for himself,' which does not acknowledge the claims of the sovereign. Mo's is 'to love all equally,' which does not acknowledge the peculiar affection due to a father. But to acknowledge neither king nor father is to be in the state of a beast. The way of benevolence and righteousness is stopped up."

On this seething ocean of lawlessness, wickedness, heresies, and misery Mencius looked out from the quiet of his school, and his spirit was stirred within him to attempt the rescue of the people from the misrule and error. It might be that he would prove the instrument for this purpose. "If Heaven," he said, "wishes that the kingdom should enjoy tranquillity and good order, who is there besides me to bring it about?" He formed his plan, and proceeded to put it in execution. He would go about among the different kings till he should find one among them who would follow his counsels and commit to him the entire administration of his government. That obtained, he did not doubt that in a few years there would be a kingdom so strong and so good that all rulers would acknowledge its superiority, and the people hasten from all quarters to crown its sovereign as monarch of the whole of China. This plan was much the same as that of Confucius had been; but, with the bolder character that belonged to him, Mencius took in one respect a position from which "the master" would have shrunk. The former was always loyal to Châu, and thought he could save the country by a reformation; the latter saw the day of Châu was past, and the time was come for a revolution. Mencius's view was the more correct, but he was not wiser than the sage in forecasting for the future. They could think only of a reformed dynasty or of a changed dynasty, ruling according to the model principles of a feudal constitution, which they described in glowing language. They desired a repetition of the golden age in the remote past; but soon after Mencius disappeared from the stage of life there came the sovereign of Ch'in, and solved the question with fire and sword, introducing the despotic empire which has since prevailed.

An inquiry here occurs—"How, in the execution of his plan, was Mencius, a scholar, without wealth or station, to find admission to the courts of lawless and unprincipled kings, and acquire the influence over them which he expected?" It can only be met by our bearing in mind the position accorded from the earliest times in China to men of virtue and ability. The same written character denotes both scholars and officers. They are at the top of the social scale,—the first of the four classes into which the population has always been divided. This appreciation of learning or culture has exercised a most powerful influence over the government under both conditions of its existence; and out of it grew the system, which was organized and consolidated more than a thousand years ago, of making literary merit the passport to official employment. The ancient doctrine was that the scholar's privilege was from Heaven as much as the sovereign's right; the modern system is a device of the despotic rule to put itself in Heaven's place, and have the making of the scholar in its own hands. The feeling and conviction out of which the system grew prevailed in the time of Mencius. The dynasties that had successively ruled over the kingdom had owed their establishment not more to the military genius of their founders than to the wisdom and organizing ability of the learned men, the statesmen, who were their bosom friends and trusted counsellors. Why should not he become to one of the princes of his day what Î Yin had been to Thang, and Thâi-kung Wang to King Wân, and the duke of Châu to Wû and Ch'ăng? But, though Mencius might be the equal of any of those worthies, he knew of no prince like Thang and the others, of noble aim and soul, who would welcome and adopt his lessons. In his eagerness he overlooked this condition of success for his enterprise. He might meet with such a ruler as he looked for, or he might reform a bad one, and make him the coadjutor that he required. On the strength of these peradventures, and attended by several of his disciples, Mencius went for more than twenty years from one court to another, always baffled, and always ready to try again. He was received with great respect by kings and princes. He would not enter into the service of any of them, but he occasionally accepted honorary offices of distinction; and he did not scruple to receive large gifts which enabled him to live and move about as a man of wealth. In delivering his message he was as fearless and outspoken as John Knox. He lectured great men, and ridiculed them. He unfolded the ways of the old sage kings, and pointed out the path to universal sway; but it was all in vain. He could not stir any one to honourable action. He confronted heresy with strong arguments and exposed it with withering sarcasm; but he could work no deliverance in the earth. The last court at which we find him was that of Lû, probably in 310 B.C. The marquis of that state had given office to Yo-chăng, one of Mencius's disciples, and he hoped that this might be the means of a favourable hearing for himself. So it had nearly happened. On the suggestion of Yo-chăng the marquis had ordered his carriage to be yoked, and was about to step into it, and proceed to bring Mencius to his palace, when an unworthy favourite stepped in and diverted him from his purpose. The disciple told his master what had occurred, reproaching the favourite for his ill-timed intervention; Mencius, however, said to him, "A man's advancement or the arresting of it may seem to be effected by others, but is really beyond their power. My not finding in the marquis of Lû a ruler who would confide

in me and put my lessons in practice is from Heaven." He accepted this incident as a final intimation to him of the will of Heaven. He had striven long against adverse circumstances, but now he bowed in submission. We lose sight of him. He withdrew from courts and the public arena. We have to think of him, according to tradition, passing the last twenty years of his life in the congenial society of his disciples, discoursing to them, and giving the finishing touches to the record of his conversations and opinions, which were afterwards edited by them, and constitute his works. Living, he may have been a failure; dead, yet speaking in them, he has been a great power among the ever-multiplying millions of his countrymen. Nor will any thinker of the West refer to them without interest and benefit. Mencius was not so oracular, nor so self-contained, as Confucius; but his teachings have a vivacity and sparkle of which we never weary, and which is all their own.

We will now attempt to indicate briefly the more important principles which our philosopher thought would have been effectual to regenerate his country, and make an end of misery and heresy within its borders.

And first as to his views on government, and the work to be done by rulers for their subjects. Mencius held with Confucius—and it was a doctrine which had descended to them both from the remotest antiquity—that royal government is an institution of God. An ancient sovereign had said that "Heaven, having produced the people, appointed for them rulers, and appointed for them teachers, who should be assisting to God." Our philosopher, adopting this doctrine, was led by the manifest incompetency of all the rulers of his time to ask how it could be known on what individual the appointment of Heaven had fallen or ought to fall, and he concluded that this could be ascertained only from his personal character and his conduct of affairs. The people must find out the will of Heaven as to who should be their ruler for themselves. There was another old saying which delighted Mencius,—"Heaven sees as the people see; Heaven hears as the people hear." He taught accordingly that, while government is from God, the governors are from the people;—*vox populi vox Dei*.

No claim then of a "divine right" should be allowed to a sovereign if he were not exercising a rule for the good of the people. "The people are the most important element in a nation; the altars to the spirits of the land and grain are the second; the sovereign is the lightest." Mencius was not afraid to follow this utterance to its consequences. The monarch whose rule is injurious to the people, and who is deaf to remonstrance and counsel, should be dethroned. In such a case "killing is no murder."

But who is to remove the sovereign that thus ought to be removed? Mencius had three answers to this difficult question. First, he would have the members of the royal house perform the task. Let them disown their unworthy head, and appoint some better individual of their number in his room. If they could not or would not do this, he thought, secondly, that any high minister, though not allied to the royal house, might take summary measures with the sovereign, assuming that he acted purely with a view to the public weal. His third and grand device was what he called "the minister of Heaven." When the sovereign had become a pest instead of a blessing, he believed that Heaven would raise up some one for the help of the people, some one who should so conduct himself in his original subordinate position as to draw all eyes and hearts to himself. Let him then raise the standard not of rebellion but of righteousness, and he could not help attaining to the highest dignity. Mencius hoped to find one among the rulers of his day who might be made into such a minister, and he counselled one and another to adopt measures with that object. It was in fact counselling rebellion, but he held that the house of Châu had forfeited its title to the throne.

What now were the attributes which Mencius considered necessary to constitute a good government according to his ideal of it? It must be animated by a spirit of benevolence, and ever pursue a policy of righteousness. Its aims must be, first, to make the people well off, and next, to educate them. No one was fit to occupy the throne who could be happy while any of the people were miserable, who delighted in war, who could indulge in palaces and parks which the poorest did not in a measure share with him. Game laws received his emphatic condemnation. Taxes should be light, and all the regulations for agriculture and commerce of a character to promote and encourage them. The rules which he suggested to secure those objects had reference to the existing condition of his country, but they are susceptible of wide application. They carry in them schemes of drainage and irrigation for land, and of free trade for commerce. But it must be, he contended, that a sufficient and certain livelihood be secured for all the people. Without this their minds would be unsettled, and they would proceed to every form of wild licence. They would break the laws, and the ruler would punish them,—punish those whom his neglect of his own duties had plunged into poverty, of which crime was the consequence. He would be, not their ruler, but their "trapper."

Supposing the people to be made well off, Mencius taught that education should be provided for them all. He gave the marquis of Thang a programme of four kinds of educational institutions, which he wished him to establish in his state—in the villages and the towns, for the poor as well as the rich, so that none might be ignorant of their duties in the various relations of society. But after all, unless the people could get food and clothing by their labour, he had not much faith in the power of education to make them virtuous. Give him, however, a government fulfilling the conditions that he laid down, and he was confident there would soon be a people, all contented, all virtuous. And he saw nothing to prevent the realization of such a government. Any ruler might become, *if he would*, "the minister of Heaven," who was his ideal, and the influence of his example and administration would be all-powerful. The people would flock to him as their parent, and help him to do justice on the foes of truth and happiness. Pulse and grain would be abundant as water and fire, and the multitudes, well clothed, and well principled, would sit under the shade of their mulberry trees, and hail the ruler "king by the grace of Heaven."

Secondly, as to Mencius's views about human nature. His conviction of the goodness of that encouraged him to hope for such grand results from good government, and his discussion of this subject gives his principal title to a place among philosophical thinkers.

Opinions were much divided about it among his contemporaries. Some held that the nature of man is neither good nor bad; he may be made to do good and also to do evil. Others held that the nature of some men is good, and that of others bad; thus it is that the best of men sometimes have bad sons, and the worst of men good sons. It was also maintained that the nature of man is evil, and whatever good appears in it is the result of cultivation. In opposition to all these views Mencius contended that the nature of man is good. "Water," he said, "will flow indifferently to the east or west; but will it flow indifferently up or down? The tendency of man's nature to goodness is like the tendency of water to flow downwards. By striking water you may make it leap over your forehead; and by damming and leading it you may make it go up a hill. But such movements are not according to the nature of water; it is the force applied which causes them. When men do what is not good, their nature has been dealt with in this way."

Mencius had no stronger language than this,—as indeed it would be difficult to find any stronger,—to declare his belief of the goodness of human nature. With various, but equally felicitous, illustration he replied to his different opponents. Sometimes he may seem to express himself too strongly, but an attentive study of his writings shows that he is speaking of our nature in its ideal, and not as it actually is,—as we may ascertain, by an analysis of it, that it was intended to be, and not as it has been made to become. In fact, his doctrine of human nature is hardly to be distinguished from that of Bishop Butler, while the Christian prelate is left far behind so far as charm of style is concerned.

Our author insists on the constituents of human nature, dwelling especially on the principles of benevolence, righteousness, propriety, and wisdom or knowledge, the last including the judgment of conscience. "These," said he, "are not infused into us from without. Men have these four principles just as they have their four limbs." But man has also instincts and appetites which seek their own gratification without reference to righteousness or any other control. He met this difficulty by contending that human nature is a constitution, in which the higher principles are designed to rule the lower. "Some constituents of it are noble and some ignoble, some great and some small. The great must not be injured for the small, nor the noble for the ignoble."

One of his most vigorous vindications of his doctrine is the following:—"For the mouth to desire flavours, the eye colours, the ear sounds, and the four limbs ease and rest belong to man's nature. An individual's lot may restrict him from the gratification of them; and in such a case the superior man will not say, 'My nature demands that pleasure, and I *will* get it.' On the other hand, there are love between father and son, righteousness between ruler and minister, the rules of ceremony between host and guest, and knowledge seen in recognizing the able and virtuous, and in the sage's fulfilling the heavenly course;—these are appointed (by Heaven). But they also belong to our nature, and the superior man will not say, 'The circumstances of my lot relieve me from them.'" In his preliminary dissertation to the 7th edition of this encyclopædia, Sir James Mackintosh has said that in his sermons on human nature Butler "taught truths more worthy of the name of discovery than any in the same department of inquiry with

which we are acquainted; if we ought not to except the first steps of the Grecian philosophers towards a theory of morals." Mencius was senior to Zeno, the one of those philosophers to whom Butler has most affinity, and it does not appear that he had left anything for either of them to discover.

When he proceeded from his ideal of human nature to account for the phenomena of conduct so different from what they ought to be according to that ideal, he was necessarily less successful. They puzzled him and they made him indignant and angry. "There is nothing good," he said, "that a man cannot do; he only does not do it." But why does he not do it? Against the stubborn fact Mencius beats his wings and shatters his weapons,—all in vain. He mentions a few ancient worthies who, he conceived, had always been, or who had become, perfectly virtuous. Above them all he extols Confucius, taking no notice of that sage's confession that he had not attained to conformity to his own rule of doing to others as he would have them do to him. No such acknowledgment about himself ever came from Mencius. Therein he was inferior to his predecessor: he had a subtler faculty of thought, and a much more vivid imagination; but he did not know himself nor his special subject of human nature so well.

Our limits will not allow us to go into a detail of his views on other special subjects. A few passages illustrative of his style and general teachings will complete all that can be said of him here. His thoughts, indeed, were seldom condensed like those of "the master" into aphorisms, and should be read in their connexion; but we have from him many words of wisdom that have been as goads to millions for more than two thousand years. For instance:—

"Though a man may be wicked, yet, if he adjust his thoughts, fast, and bathe, he may sacrifice to God."

"When Heaven is about to confer a great office on any man, it first exercises his mind with suffering, and his sinews and bones with toil. It exposes his body to hunger, subjects him to extreme poverty, and confounds his undertakings. In all these ways it stimulates his mind, strengthens his nature, and supplies his incompetencies"

"The great man is he who does not lose his child-heart."

"The sense of shame is to a man of great importance. When one is ashamed of having been without shame, he will afterwards not have occasion for shame."

"To nourish the heart there is nothing better than to keep the desires few. Here is a man whose desires are few: in some things he may not be able to keep his heart, but they will be few. Here is a man whose desires are many; in some things he may be able to keep his heart, but they will be few."

"Benevolence is the distinguishing characteristic of man. As embodied in his conduct, it may be called the path of duty."

"There is an ordination for everything; and a man should receive submissively what may be correctly ascribed thereto. He who has the correct idea of what Heaven's ordination is will not stand beneath a tottering wall. Death sustained in the discharge of one's duties may be correctly ascribed to Heaven. Death under handcuffs and fetters cannot be correctly so ascribed."

"When one by force subdues men, they do not submit to him in heart. When he subdues them by virtue, in their hearts' core they are pleased, and sincerely submit."

Two translations of the works of Mencius are within the reach of European readers:—that by the late Stanislaus Julien, in Latin, Paris, 1824–29; and that forming the second volume of Legge's *Chinese Classics*, Hong Kong, 1862. The latter has been published at London (1875) without the Chinese text. See also E. Faber. *The Mind of Mencius, or Political Economy founded on Moral Philosophy*, translated from the German by A. B. Hutchinson (London, 1882). (J. LE.)

MENDELSSOHN, FELIX (1809–1847). Jakob Ludwig Felix Mendelssohn-Bartholdy, one of the greatest composers of this century, was the grandson of Moses Mendelssohn noticed below, and was born in Hamburg on February 3, 1809.

In consequence of the troubles caused by the French occupation of Hamburg, Abraham Mendelssohn, his father, migrated in 1811 to Berlin, where his grandmother, Fromet, then in the twenty-fifth year of her widowhood, received the whole family into her house, No. 7 Neue Promenade. Here the little Felix and his sister Fanny received their first instruction in music from their mother, under whose care they progressed so rapidly that the altogether exceptional character of their talent soon became unmistakably apparent. Their next teacher was Madame Bigot, who, during the temporary residence of the family in Paris in 1816, gave them some valuable instruction. On their return to Berlin they took lessons in thoroughbass and composition from Zelter, in pianoforte-playing from Ludwig Berger, and in violin-playing from Henning,—the care of their general education being entrusted to the father of the novelist Paul Heyse.

Felix first played in public on the 24th of October 1818, taking the pianoforte part in a trio by Woelfl. On April 11, 1819, he entered the Berlin Singakademie as an alto, and in the following year began to compose with extraordinary rapidity. His earliest dated work is a cantata, *In rührend feierlichen Tönen*, completed on January 13, 1820. During that year alone he produced nearly sixty movements, including songs, pianoforte sonatas, a trio for pianoforte, violin, and violoncello, a sonata for violin and pianoforte, pieces for the organ, and even a little dramatic piece in three scenes. In 1821 he wrote five symphonies for stringed instruments, each in three movements; motetts for four voices; an opera, in one act, called *Soldatenliebschaft*; another, called *Die beiden Pädagogen*; part of a third, called *Die wandernde Comödianten*; and an immense quantity of other music of different kinds, some of which, thought worthy of publication by the editors of his posthumous works, now stands before the world in evidence of the precocity of his genius. The original autograph copies of these early productions are now preserved in the Berlin Library, where they form part of a collection which fills forty-four large volumes, all written with infinite neatness, and for the most part carefully dated—a sufficient proof that the methodical habits which distinguished his later life were formed in early childhood.

In 1821 Mendelssohn paid his first visit to Goethe, with whom he spent sixteen days at Weimar, in company with Zelter. From this year also dates his first acquaintance with Weber, who was then in Berlin superintending the production of *Der Freischütz*; and from the summer of 1822 his introduction, at Cassel, to another of the greatest of his contemporaries, Ludwig Spohr. During this year his pen was even more prolific than before, producing, among other works, an opera, in three acts, entitled *Die beiden Neffen, oder Der Onkel aus Boston*, and a pianoforte concerto, which he played in public at a concert given by Frau Anna Milder.

It had long been a custom with the Mendelssohn family to give musical performances on alternate Sunday mornings in their dining-room, with a small orchestra, which Felix always conducted, even when he was not tall enough to be seen without standing upon a stool. For each of these occasions he produced some new work,—playing the pianoforte pieces himself, or entrusting them to Fanny, while his sister Rebecka sang, and his brother Paul played the violoncello. In this way *Die beiden Neffen* was first privately performed, on the fifteenth anniversary of his birthday, February 3, 1824. Between the 3d and the 31st of March, in this year, he composed his fine symphony in C minor, now known as Op. 10, and soon afterwards the quartett in B minor, Op. 3, and the (posthumous) pianoforte sestett, Op. 110. In this year also began his lifelong friendship with Moscheles, who, when asked to receive him as a pupil, said, "If he wishes to take a hint from me, as to anything new to him, he can easily do so; but he stands in no need of lessons."

In 1825 Abraham Mendelssohn took Felix to Paris, where among other musicians then resident in the French capital he met the two most popular dramatic composers of the age, Rossini and Meyerbeer, and lived on terms of intimacy with Hummel, Kalkbrenner, Rode, Baillot, Herz, and many other artists of European celebrity. On this occasion, also, he made his first acquaintance with Cherubini, who, though he rarely praised any one, expressed a very high opinion of his talent, and recommended him to write a *Kyrie*, for five voices, with full orchestral accompaniments, which he himself described as "exceeding

in thickness" anything he had attempted. From letters written at this period we learn that Felix's estimate of the French school of music was very far from a flattering one; but he formed some friendships in Paris, which were pleasantly renewed on later occasions. He returned to Berlin with his father in May 1825, taking leave of his Parisian friends on the 19th of the month, and interrupting his journey at Weimar for the purpose of paying a second visit to Goethe, to whom he dedicated his quartett in B minor. On reaching home he must have fallen to work with greater zeal than ever; for on the 23d of July in this same year he completed his pianoforte capriccio in F sharp minor (Op. 5), and on the 10th of August an opera, in two acts, called *Die Hochzeit des Camacho,* a work of considerable importance, concerning which we shall presently have to speak more particularly.

No ordinary boy could have escaped uninjured from the snares attendant upon such a life as that which Mendelssohn now lived. Notwithstanding his overwhelming passion for music, his general education had been so well cared for that he was able to hold his own, in the society of his seniors, with the easy grace of an accomplished man of the world. He was already recognized as a leading spirit by the artists with whom he associated, and these artists were men of acknowledged talent and position. The temptations to egoism by which he was surrounded would have rendered most clever students intolerable. But the natural amiability of his disposition, and the healthy influence of his happy home-life, counteracted all tendencies towards inordinate self-assertion; and he is described by all who knew him at this period as the most charming boy imaginable. Even Zelter, though by nature no less repressive than Cherubini, was not ashamed to show that he was proud of him; and Moscheles, whose name was already famous, met him from the first on equal terms.

Soon after his return from Paris, Abraham Mendelssohn removed from his mother's residence to No. 3 Leipziger Strasse, a roomy, old-fashioned house, containing an excellent music-room, and in the grounds adjoining a "Gartenhaus" capable of accommodating several hundred persons at the Sunday performances.[1] In the autumn of the following year this "garden-house" witnessed a memorable private performance of the work by means of which the greatness of Mendelssohn's genius was first revealed to the outer world—the overture to Shakespeare's *Midsummer Night's Dream.* The finished score of this famous composition is dated "Berlin, August 6, 1826,"—that is to say, three days after its author had attained the age of seventeen years and a half. Yet we may safely assert that in no later work does he exhibit more originality of thought, more freshness of conception, or more perfect mastery over the details of technical construction, than in this delightful inspiration, which, though now nearly sixty years old, still holds its place at the head of the most brilliant achievements of our modern schools. The overture was first publicly performed at Stettin, in February 1827, under the direction of the young composer, who with this bright patent of artistic nobility to support his claim, was at once accepted as the leader of a new and highly characteristic manifestation of the spirit of modern progress. Henceforth therefore we must speak of him, not as a student, but as a mature and experienced artist.

Meanwhile *Camacho's Wedding* had been submitted to Herr General-Musik-Director Spontini, with a view to its production at the opera. The libretto, founded upon an episode in the history of Don Quixote, was written by Klingemann, and Mendelssohn threw himself into the spirit of the romance with a keen perception of its peculiar humour. The work was put into rehearsal soon after the composer's return from Stettin, produced on April 29, 1827, and received with great apparent enthusiasm; but, for some reason which it is now impossible to ascertain, a cabal was formed against it, and it never reached a second performance. The critics abused it mercilessly; yet it exhibits merits of a very high order. The solemn passage for the trombones, which heralds the first appearance of the knight of La Mancha, is conceived in a spirit of reverent appreciation of the idea of Cervantes, which would have done honour to a composer of lifelong experience. Even the critics suborned to condemn the work could not refrain from expressing their admiration of this; but it had been decreed that the opera should not live—and it did not.

Mendelssohn was excessively annoyed at this injustice, and some time elapsed before his mind recovered its usual bright tone; but he continued to work diligently for the cause of art. Among other serious undertakings, he formed a choir for the study of the great choral works of Sebastian Bach, then entirely unknown to the public; and, in spite of Zelter's determined opposition, he succeeded, in 1829, in inducing the Berlin Singakademie to give a public performance of the *Passion according to St Matthew*, under his direction, with a chorus of between three and four hundred voices. The scheme succeeded beyond his warmest hopes, and proved the means of restoring to the world great compositions with which we are all now familiar, but which, at that time, had never been heard since the death of Bach. But the obstructive party were grievously offended; and at this period Mendelssohn was far from popular among the musicians of Berlin.

In April 1829 Mendelssohn paid his first visit to London. His reception was most enthusiastic. He made his first appearance before an English audience at one of the Philharmonic Society's concerts—then held in the Argyll Rooms—on the 25th of May, conducting his symphony in C minor from the pianoforte, to which he was led by John Cramer. On the 30th he played Weber's *Concertstück*, from memory, a proceeding at that time extremely unusual. At a concert given by Drouet, on the 24th of June, he played Beethoven's pianoforte concerto in E flat, which had never before been heard in the country; and the overture to *A Midsummer Night's Dream* was also, for the first time, presented to a London audience. On returning home from the concert, Mr Attwood, then organist of St Paul's Cathedral, left the score of the overture in a hackney coach, whereupon Mendelssohn wrote out another, from memory, without an error. At another concert he played, with Moscheles, his still unpublished concerto in E, for two pianofortes and orchestra. After the close of the London season he started with Klingemann on a tour through Scotland, where he was inspired with the first idea of his overture to *The Isles of Fingal*, returning to Berlin at the end of November. Except for an accident to his knee, which lamed him for some considerable time, his visit was a highly successful one, and laid the foundation of many firm friendships and many prosperous negotiations in the time to come.

The visit to England formed in reality the first division only of a great scheme of travel which his father wished him to extend to all the most important art centres in Europe. After refusing the offer of a professorship at Berlin, he started again, in May 1830, for Italy, pausing on his way at Weimar, where he spent a memorable fortnight with Goethe, and reaching Rome, after many pleasant interruptions, on November 1. No possible form of excitement ever prevented him from devoting a certain time every day to composition; but he lost no opportunity

[1] After Mendelssohn's death this house was sold to the Prussian Government; and the "Herrenhaus" now stands on the site of the garden-house.

raised to the highest position attainable in the German musical world. To this new sphere of labour he removed in August 1835, opening the first concert at the Gewandhaus, on the 4th of October, with his overture *Die Meeresstille*, a work possessing great attractions, though by no means on a level with the *Midsummer Night's Dream*, *The Isles of Fingal*, or *Melusine*.

Mendelssohn's reception in Leipsic was most enthusiastic; and under their new director the Gewandhaus concerts prospered exceedingly. Meanwhile *St Paul* steadily progressed, and was first produced, with triumphant success, at the Lower Rhine festival at Düsseldorf, on May 22, 1836. On October 3 it was first sung in English, at Liverpool, under the direction of Sir George Smart; and on March 16, 1837, Mendelssohn again directed it at Leipsic.

The next great event in Mendelssohn's life was his happy marriage, on March 28, 1837, to Cecile Charlotte Sophie Jeanrenaud, whose amiable disposition, surpassing beauty, and indescribable charm of manner endeared her to all who knew her. The honeymoon was scarcely over before he was again summoned to England to conduct *St Paul*, at the Birmingham festival, on September 20th. During this visit he played on the organ at St Paul's and at Christ Church, Newgate Street, with an effect which exercised a lasting influence upon English organists. It was here also that he first contemplated the production of his second oratorio, *Elijah*.

Passing over the composition of the *Lobgesang* in 1840, a sixth visit to England in the same year, the scheme for the erection of a monument to Sebastian Bach, and other events on which space does not permit us to enlarge, we find Mendelssohn in 1841 recalled to Berlin by the king of Prussia, with the title of Kapellmeister. Though this appointment resulted in the production of *Antigone*, *Œdipus Coloneus*, *Athalie*, the incidental music to the *Midsummer Night's Dream*, and other great works, it proved an endless source of vexation, and certainly helped to shorten the composer's life. In 1842 he came to England for the seventh time, accompanied by his wife, conducted his Scotch symphony at the Philharmonic, again played the organ at St Peter's, Cornhill, and Christ Church, Newgate Street, and was received with all possible honour by the queen and the prince consort. He did not, however, permit his new engagements to interfere with the direction of the Gewandhaus concerts; and in 1843 he founded in Leipsic the great conservatoire which soon became the best musical college in Europe, opening it on April 3, in the buildings of the Gewandhaus. In 1844 he conducted six of the Philharmonic concerts in London, producing his new *Midsummer Night's Dream* music, and playing Beethoven's pianoforte concerto in G with extraordinary effect. He returned to his duties at Berlin in September, but happily succeeded in persuading the king to free him from his most onerous engagements, and his delight at this relief was unbounded.

After a brief residence in Frankfort, Mendelssohn returned to Leipsic in September 1845, resuming his old duties at the Gewandhaus, and teaching regularly in the conservatoire. Here he remained, with little interruption, during the winter,—introducing his friend Jenny Lind, then at the height of her popularity, to the critical frequenters of the Gewandhaus, and steadily working at *Elijah*, the first performance of which he conducted at the Birmingham festival, on August 26, 1846. The enthusiastic reception of this great work is well known. Unhappily, the excitement attendant upon its production, added to the irritating effect of the worries at Berlin, made a serious inroad upon the composer's health. On his return to Leipsic he worked on as usual, but it was

clear that his health was seriously impaired. In 1847 he visited England for the tenth and last time, to conduct four performances of *Elijah* at Exeter Hall, on the 16th, 23d, 28th, and 30th of April, one at Manchester on the 20th, and one at Birmingham on the 27th. Again the queen and prince consort received him with marked respect,—one might almost venture to say, affection,—and all seemed prosperous and happy. But the necessary exertion was far beyond his strength. He witnessed Jenny Lind's first appearance at Her Majesty's Theatre, on the 4th of May, and left England on the 9th, little anticipating the trial that awaited him in the tidings of the sudden death of his sister Fanny, which reached him only a few days after his arrival in Frankfort. The loss of his mother in 1842 had shaken him much, but the suddenness with which this last sad intelligence was communicated broke him down completely. He fell to the ground insensible, and never fully recovered. In June he was so far himself again that he was able to travel, with his family, by short stages, to Interlaken, where he stayed for some time, illustrating the journey by a series of water-colour drawings, but making no attempt at composition for many weeks. He returned to Leipsic in September, bringing with him fragments of *Christus*, *Loreley*, and some other unfinished works, taking no part in the concerts, and living in the strictest privacy. On the 9th of October he called on Madame Frege, and asked her to sing his latest set of songs. She left the room for lights, and on her return found him in violent pain, and almost insensible. It was the beginning of the end. He lingered on, now better now worse, through four weary weeks, and on the 4th of November he passed away, in the presence of his wife, his brother, and his three dear friends, Moscheles, Schleinitz, and Ferdinand David. A cross now marks the site of his grave, in the Alte Dreifaltigkeits Kirchhof, at Berlin.

Mendelssohn's title to a place among the greatest composers of the century is incontestable. His style, though differing but little in technical arrangement from that of his classical predecessors, is characterized by a vein of melody peculiarly his own, and easily distinguishable by those who have studied his works, not only from the genuine effusions of contemporary writers, but from the most successful of the servile imitations with which, even during his lifetime, the music-shops were deluged. In less judicious hands the rigid symmetry of his phrasing might, perhaps, have palled upon the ear; but under his skilful management it serves only to impart an additional charm to thoughts which derive their chief beauty from the evident spontaneity of their conception. In this, as in all other matters of a purely technical character, he regarded the accepted laws of art as the medium by which he might most certainly attain the ends dictated by the inspiration of his genius. Though caring nothing for rules, except as means for producing a good effect, he scarcely ever violated them, and was never weary of impressing their value upon the minds of his pupils. His method of counterpoint was modelled in close accordance with that practised by Sebastian Bach. This he used in combination with an elastic development of the sonata-form, similar to that engrafted by Beethoven upon the lines laid down by Haydn. The principles involved in this arrangement were strictly conservative; yet they enabled him, at the very outset of his career, to invent a new style no less original than that of Schubert or Weber, and no less remarkable as the embodiment of canons already consecrated by classical authority than as a special manifestation of individual genius. It is thus that Mendelssohn stands before us as at the same time a champion of conservatism and an apostle of progress; and it is chiefly by virtue of these two apparently incongruous though really perfectly compatible phases of his artistic character that his influence and example have, for so many years, held in check the violence of reactionary opinion which a little injudicious encouragement might easily have fanned into revolutionary fury. Happily, this wholesome influence is still at work among us; and in his oratorios, his symphonies, his overtures, his concertos, and his smaller pianoforte pieces Mendelssohn sets before us an example the value of which is universally recognized, and not likely to be soon forgotten.

Concerning Mendelssohn's private character there have never been two opinions. As a man of the world, he was more than ordinarily accomplished,—brilliant in conversation, and in his lighter moments overflowing with sparkling humour and ready pleasantry, loyal and unselfish in the more serious business of life, and never weary of working for the general good. As a friend he was unvaryingly kind, sympathetic, and as true as steel. His earnestness as a Christian needs no stronger testimony than that afforded by his own delineation of the character of St Paul; but it is not too much to say that his heart and life were pure as those of a little child.

A complete list of Mendelssohn's published compositions—one hundred and nineteen in number, besides some five and twenty unnumbered works of considerable importance—will be found in the thematic catalogue published by Messrs Breitkopf and Härtel at Leipsic, and also in Grove's *Dictionary of Music and Musicians*, vol. ii. pp. 308, 309. Among his miscellaneous writings, we may mention a translation of the *Andria* of Terence, in German verse, and an immense collection of letters, posthumously printed, and calculated to give the reader a far closer acquaintance with his life and character than any biographer can hope to convey. (W. S. R.)

MENDELSSOHN, Moses (1729-1786), philosopher and scholar, well known as Lessing's friend and the prototype of his "Nathan," was born on September 6, 1729, at Dessau on the Elbe, where his Jewish father made a scanty livelihood by teaching a small school and transcribing copies of the "law." The leading events of Mendelssohn's career have been indicated elsewhere (see Jews, vol. xiii. p. 680). His numerous writings include *Ueber Evidenz in metaphysischen Wissenschaften* (1763), which gained the prize in a competition in which Immanuel Kant took part; *Briefe über die Empfindungen* (1764); *Phædon, oder über die Unsterblichkeit der Seele* (1767), an argument for immortality, founded on the nature of the soul as exempting it from the ordinary laws of change, which has been severely criticized by Kant; *Jerusalem, oder die religiöse Macht und Judenthum* (1783), a specially important contribution to the question of Jewish emancipation; a number of contributions to his friend Nicolai's *Literaturbriefen* and *Bibliothek der schönen Wissenschaften*; one or two tracts in Hebrew; and some new German translations from the Old Testament. The controversy which led to the publication of his *Morgenstunden* (1785-86), a reply to Jacobi's *Briefe über die Lehre Spinoza's*, is said to have been more or less directly the cause of his death, which took place on January 4, 1786 (see Jacobi, vol. xiii. p. 537). Of Mendelssohn's three sons, the second, Abraham, settled as a banker in Hamburg and married a Jewess, Lea Salomon Bartholdy, who bore him four children; these, by advice of their mother's brother, himself a conscientious convert from Judaism, were educated as Christians, and thenceforth joined their mother's second surname to their own. The second of them, Felix, is the subject of the preceding notice. In later life Abraham Mendelssohn was accustomed to say,—"When I was young I was the son of my father; now I am the father of my son." See *The Mendelssohn Family*, 1882.

MENDOZA, a city of the Argentine Republic, the only town of the province of Mendoza, lies 700 miles west-north-west of Buenos Ayres, at the foot of the Cordilleras, 2510 feet above the sea-level, in 32° 53′ S. lat. and 68° 45′ W. long. It was formerly a frequent stopping-place on the route across the Andes by the Uspallata Pass, and used to rank as one of the best-built towns in the country, but in 1861 it was almost completely destroyed by an appalling earthquake, in which the people, for the most part collected in the churches, perished to the number of about 12,000. Bravard, a French geologist who had often predicted the catastrophe, was one of those who perished. Extensive ruins still mark the site of the old town; the new town, which has been built at a little distance, has grown rapidly. Situated in a richly cultivated district, Mendoza depends mainly on agriculture and fruit-growing.

The city was founded in 1559 by Garcia de Mendoza; and in 1776 it was made the administrative centre of the vice-royalty of La Plata. See Mulhall, *Handbook of the La Plata States*, 1875; and Mrs Mulhall, *Between the Amazon and the Andes*, 1882.

MENDOZA, Diego Hurtado de (c. 1503-1575), novelist, poet, diplomatist, and historian, was a younger son of the member of the illustrious Mendoza family to whom

the government of Granada was entrusted not long after its surrender, and was born in that city about the year 1503. The marquis of Santillana, so prominent a figure at the court of John II. of Castile, was his great-grandfather. At an early age Mendoza, who had been destined for the church, was sent to Salamanca, where he studied with success, and also, some time between the years 1520 and 1525, produced his *Lazarillo de Tormes*, the work upon which his literary celebrity largely rests. Having persuaded his father to allow him to enter the army, he served with the Spanish troops of Charles V. in Italy, and also availed himself of opportunities as they arose to hear the lectures of famous professors at Bologna, Padua, and Rome. In 1538 he was taken into the diplomatic service of the emperor and sent as ambassador to Venice; there he cultivated friendly relations with the Aldi, and energetically set about collecting a library, not only procuring copies of many old MSS. in the public library of the city, but also sending to Thessaly and Mount Athos for new ones; it was from his collection that the complete text of Josephus was first printed. For some time he held the post of military governor of Siena; and, after having been present in an official capacity in Trent at the beginning of the œcumenical council, he was in 1547 sent as special plenipotentiary to Rome, where he continued to act for some years. In 1554, shortly before the abdication of Charles, he was recalled to Spain, and his official career came to an end. He was never a favourite with Philip II.; and in consequence of a quarrel with a courtier, in which he had lost his temper badly, he was finally banished from court in 1568. The remaining years of his life, which were spent at Granada, he devoted partly to the study of Arabic, partly to poetical composition, and partly to the preparation of his history of the Moorish insurrection of 1568–70 (*Guerra de Granada*). He died at Madrid (which he had obtained leave to visit on some business errand) in April 1575.

Mendoza's *Lazarillo de Tormes*, though written during his college days, was not published until 1553, when it was printed anonymously at Antwerp. Next year it was reprinted at Burgos, but ultimately it was taken exception to by the Inquisition, and the Spanish editions of 1573 and subsequent years are accordingly considerably abridged. It is a comparatively short fragment, written in vigorous and bright Castilian, and was the first example in modern literature of the "novela picaresca" of which Le Sage's *Gil Blas* now ranks as the most perfect specimen. The continuations, first by an anonymous author (1555) and afterwards by H. de Luna (1620), are of very inferior interest. Of Mendoza as a poet all that need be said here is that he followed the modern Italian models quite as far as was compatible with a due regard to his Castilian individuality. His history, though of no great bulk, is, like his novel, a work of remarkable literary execution. It relates indeed only to a comparatively brief episode in a chapter of events for which it is almost impossible to claim much general attention, and it is often needlessly erudite and sometimes provokingly obscure. But as a whole it is singularly well-informed, dignified, and picturesque; "the style is bold and abrupt, but true to the idiom of the language, and the current of thought is deep and strong, easily carrying the reader onward with its flood. Nothing in the old chronicling style of the earlier period is to be compared to it, and little in any subsequent period is equal to it for manliness, vigour, and truth" (Ticknor). The first edition of the *Guerra de Granada* did not appear until 1610, but was even then incomplete; the first perfect edition was that of 1730. The work has frequently been reprinted since.

MENDOZA, Iñigo Lopez de. See Santillana.

MENELAUS, king of Sparta, was the brother of Agamemnon (*q.v.*) and the husband of Helena (*q.v.*). He was one of the heroes of the Trojan horse, and recovered his wife at the sack of the city. On the voyage homewards his fleet was scattered off Malea by a storm which drove him to Crete; after seven years' further wandering to Cyprus, Phœnicia, Egypt, Ethiopia, Libya, and the country of the Erembi, he at last had an interview with Proteus and obtained a favourable wind which brought him home on the very day on which Orestes was holding the funeral feast over Ægisthus and Clytæmnestra. After a long and happy life in Lacedæmon, Menelaus, as the son-in-law of Zeus, did not die but was translated to Elysium.

MENGS, Antony Raphael (1728–1779), was the most celebrated representative of the eclectic school of painting in the 18th century, and played a great part in the early days of the classic revival. He was born in 1728 at Aussig in Bohemia, but his father, a Danish painter, established himself finally at Dresden, whence in 1741 he conducted his son to Rome. Mengs early showed that active intelligence and large capacity for laborious study which secured him the extraordinary distinction which he enjoyed through life. His appointment in 1749 as first painter to the elector of Saxony did not prevent his spending much time in Rome, where he had married in 1748, and abjured the Protestant faith, and where he became in 1754 director of the Vatican school of painting, nor did this hinder him on two occasions from obeying the call of Charles III. of Spain to Madrid. There Mengs produced some of his best work, and specially the ceiling of the banqueting hall, the subject of which was the Triumph of Trajan and the Temple of Glory. After the completion of this work in 1777, Mengs again returned to Rome, and there he died, two years later, in poor circumstances, leaving twenty children, seven of whom were pensioned by the king of Spain. Besides numerous paintings in the Madrid gallery, the Ascension at Dresden, Perseus and Andromeda at St Petersburg, and the ceiling of the Villa Albani must be mentioned among his chief works. In England, the duke of Northumberland possesses a Holy Family, and the colleges of All Souls and Magdalen, at Oxford, have altar-pieces by his hand. In his writings, in Spanish, Italian, and German, Mengs has put forth his eclectic theory of art, which treats of perfection as attainable by a well-schemed combination of diverse excellences,—Greek design, with the expression of Raphael, the chiaroscuro of Correggio, and the colour of Titian. His close intimacy with Winkelmann—who constantly wrote at his dictation—has greatly enhanced his historical importance, for he formed no scholars, and the critic must now concur in Goethe's judgment of Mengs in *Winkelmann und seine Jahrhundert*; he must deplore that so much learning should have been allied to a total want of initiative and utter poverty of invention, and embodied with a strained and artificial mannerism.

See *Opere di Antonio Raffaello Mengs*, Parma, 1780; *Mengs' Werke, übersetzt v. G. F. Prange*, 1786; *Zeitschrift für bildende Kunst*, 1880; Bianconi, *Elogio Storico di Mengs*, Milan, 1780; Nagler's *Künstlerlexikon*.

MENHADEN, economically one of the most important fishes of the United States, known by a great number of local names, "menhaden" and "mossbunker" being those most generally in use. In systematic works it appears under the names of *Clupea menhaden* and *Brevoortia tyrannus*. It is allied to the European species of shad and pilchard, and, like the latter, approaches the coast in its wanderings in immense shoals, which are found throughout the year in some part of the littoral waters between Maine and Florida, the northern shoals retiring into deeper water or to more southern latitudes with the approach of cold weather. The average size of the menhaden is about 12 inches. Although it was long known as a palatable table-fish, and largely used, when salted, for export to the West Indies, and as bait for cod and mackerel, the menhaden fishery has been developed to its present importance only within the last twenty years. A large fleet of steamers and sailing vessels is engaged in it; and a great number of large factories have sprung into existence to extract the oil, which is used for tanning and currying, and for adulterating other more expensive oils, and to manufacture the refuse into a very valuable guano. In the year 1877 2,426,589 gallons of oil and 55,444 tons of guano were produced.

An extensive business is also carried on in converting menhaden of a suitable size into "American sardines."

A very complete account of this fishery is given by G. Brown Goode in "The Natural and Economic History of the American Menhaden," *United States Commission of Fish and Fisheries*, part v., Washington, 1879.

MENIN, a small Belgian town, in the province of West Flanders; it is traversed by the river Lys, which there forms the boundary between France and Belgium. The population in 1880 was 10,200. Commercially and industrially Menin ranks high for its size, possessing, as it does, important manufactures of linen, oil, soap, &c., as well as sugar refineries, breweries, and tanneries, and a good corn and cattle market. Tobacco is extensively grown in the neighbourhood, and forms one of the main items of lawful trade, a good deal of illicit traffic also being carried on across the French frontier.

Menin does not appear to have been in any way worthy of note until the 14th century. Philip II. caused it to be fortified in 1578. It was taken by Turenne in 1658. Vauban subsequently surrounded it with elaborate works, and made it one of the strongest citadels in France; but all its fortifications were razed in 1744. It belonged to the Netherlands in 1815, and became part of Belgium in 1830.

MENINGITIS (from μῆνιγξ, a membrane), a term in medicine applied to inflammation affecting the membranes of the brain (cerebral meningitis) or spinal cord (spinal meningitis) or both.

Of *cerebral meningitis* there are two varieties:—(1) that due to the presence of tubercle in the membranes of the brain, which gives rise to the disease known as tubercular meningitis, or acute hydrocephalus; and (2) simple or acute meningitis, which may arise from various causes. Among the more common are injuries of the head, extension of disease from contiguous parts, such as erysipelas of the scalp or caries of the bones of the ear, exposure to cold or to extreme heat, the presence of tumours in the substance of the brain. It may likewise occur in the course of fevers, rheumatism, and inflammatory affections, and also as a result of mental overwork, sleeplessness, and alcoholic excess. This latter variety of meningitis is less common than the former, but it is on the whole more amenable to treatment. The symptoms present such a general resemblance to those already described in tubercular meningitis that it is unnecessary to refer to them in detail (see HYDROCEPHALUS), and the treatment is essentially the same for both.

Spinal meningitis, or inflammation of the membranes investing the spinal cord, generally results from causes of a similar kind to those producing cerebral meningitis,—injuries, exposure to cold or sudden changes of temperature, diseases affecting adjacent parts such as the vertebral column or the spinal cord itself, or extension downwards of inflammation of the membranes of the brain. It is said to be most common in males. As in the case of the brain, the membranes become extremely congested; exudation of lymph and effusion of serum follow; and the spinal cord and roots of the nerves become more or less involved in the morbid process.

The chief symptoms are fever, with severe pain in the back or loins shooting downwards into the limbs (which are the seat of frequent painful involuntary startings), accompanied with a feeling of tightness round the body. The local symptoms bear reference to the portion of the cord the membranes of which are involved. Thus when the inflammation is located in the cervical portion the muscles of the arms and chest are spasmodically contracted, and there may be difficulty of swallowing or breathing, or embarrassed heart's action, while when the disease is seated in the lower portion, the lower limbs and the bladder and rectum are the parts affected in this way. At first there is excited sensibility (hyperæsthesia) in the parts of the surface of the body in relation with the portion of cord affected. As the disease advances these symptoms give place to those of partial loss of power in the affected muscles, and also partial anæsthesia. These various phenomena may entirely pass away, and the patient after some weeks or months recover; or, on the other hand, they may increase, and end in permanent paralysis.

The treatment is directed to allaying the pain and inflammatory action by opiates. Ergot of rye is strongly recommended by many physicians. The patient should have perfect rest in the recumbent, or better still in the prone, position. Cold applications to the spine may be of use, while scrupulous attention to the functions of the bladder and bowels, and to the condition of the skin with the view of preventing bed-sores, is all-important.

Epidemic Cerebro-spinal Meningitis.—This name, as well as *cerebro-spinal fever*, is applied to a disease defined in the *Nomenclature of Diseases* as "a malignant epidemic fever, attended by painful contractions of the muscles of the neck and retraction of the head. In certain epidemics it is frequently accompanied by a profuse purpuric eruption, and occasionally by secondary effusions into certain joints. Lesions of the brain and spinal cord are found on dissection." This disease appears to have been first distinctly recognized in the year 1837, when it prevailed as an epidemic in the south-west of France, chiefly among troops in garrison. For several years subsequently it existed in various other localities in France, and mostly among soldiers. At the same time in other countries in western and central Europe the disease was observed in epidemic outbreaks, both among civil and military populations. In 1846 it first showed itself in Ireland, chiefly among the inmates of workhouses in Belfast and Dublin. Numerous outbreaks occurred also about the same period in many parts of the United States. In more recent times the disease has repeatedly appeared both in Europe and America, but it has seldom prevailed extensively in any one tract of country, the outbreaks affecting for the most part limited communities, such as garrisons or camps, schools, workhouses, and prisons.

Little is known regarding the causation of this disease. All ages seem liable to suffer, and, as regards sex, males are affected more commonly than females. Occupation and condition of life appear to exercise no influence. It has been observed to occur most frequently in cold seasons. The question of the contagiousness of cerebro-spinal fever remains still unsettled, but the weight of authority appears to be in favour of the theory of the communicability of the disease. It cannot, however, be regarded as contagious in the same degree as some other specific fevers, such as typhus fever, small-pox, or scarlatina.

The following are the more prominent symptoms. After a few days of general discomfort the attack comes on sharply with rigors, intense headache, giddiness, and vomiting. Neuralgic pains in the abdomen, and pain with spasmodic contractions in the muscles of the extremities, occur at an early stage. The headache continues with great severity, and restlessness and delirium supervene, accompanied with periods of somnolence. The pains and spasms rapidly increase, the muscles of the neck, spine, and limbs being specially affected. The patient's head is drawn backwards and rigidly fixed, the spine arched, and the arms and legs powerfully flexed, the whole condition bearing a considerable resemblance to tetanus. For a time there is greatly increased sensibility of the skin, pain being excited by the slightest contact. There is more or less fever present. About the fourth day of the disease an eruption on the skin both of the face and body frequently appears, in the form either of purpuric spots or small clear vesicles. Death may take place in from a few hours to eight or ten days. Should the patient survive the immediate shock of the attack, serious complications are apt to appear in the form of destructive inflammation of the eyes or ears, inflammation with effusion into certain joints, and paralysis of limbs; or, again, recovery may take place after a prolonged convalescence. The mortality appears to vary in different epidemics, in some being as high as 80 per cent., in others only about 20 per cent. Certain forms of the disease are of malignant character from the first, and very rapidly fatal.

The changes found after death in cerebro-spinal fever are intense inflammation of the membrane of the brain and spinal cord, with effusion of serum or pus into the ventricular and arachnoid spaces.

The treatment is similar to that of other febrile conditions, but for the special symptoms of pain, spasm, &c., opium seems to have been found of eminent service, while quinine and ergot of rye are also recommended.

MENNONITES is a name borne by certain Christian communities in Europe and America, denoting their adherence to a type of doctrine of which Menno Simons

was, not indeed the originator, but the chief exponent at the time when the anti-pædo-baptism of the congregations in which he laboured took permanent form in opposition to ordinary Protestantism on the one hand and to the theocratic ideas of the Münster type of anabaptism on the other. The original home of the views afterwards called Mennonite was in Zürich, where, as early as 1525, Grebel and Manz founded a community having for its most distinctive mark baptism upon confession of faith. The chief doctrines of these Zürich Baptists have been already stated in the article BAPTISTS, vol. iii. p. 353. The main interest of the sect lay not in dogma but in discipline. Within the communities evangelical life was reduced to a law of separation from the world, and this separation—enforced by a stringent use of excommunication and the prohibition of marriage beyond the brotherhood—involved not only abstinence from worldly vanities but refusal of civic duties (the state being held to be un-Christian)—refusal to take an oath or use the sword. In their revolt against the corruptions of the mediæval church the Reformers neither denied the continuity of the church as an organization nor impugned the Christian character of the state. The new sect did both; and their position thus appeared so radically subversive of the foundations of society that it is not surprising, under the imperfect views of toleration then current, that they became the objects of bitter persecution from Protestants as well as from Catholics. But the Grebelians had no desire, like the fanatics of Münster, to found a new theocracy in opposition to the anti-Christian state. They sought only to withdraw from what their conscience condemned, content to live as strangers upon earth, and devoting all their energy to preserve the purity of their own communities. The mediæval conception of separation from the world as the true path of Christian perfection had leavened all middle-class society in Europe, and prepared many to accept separatist views of the church as soon as they were reached by the impulse of revolt against Roman Catholicism; the pursuit of holiness in a society protected by a strict discipline is an idea which experience has shown to have a great attraction for one class of earnest minds; hence, in spite of persecutions incomparably fiercer than any of the larger Protestant bodies ever underwent, the new doctrine and praxis rapidly spread from Switzerland to Germany, Holland, and even to France. Each community was quite independent, united to the rest only by a bond of love. There was no sort of hierarchy, but only "exhorters" chosen by the congregation, of whom the most prominent were also "elders" entrusted with the administration of the sacraments—an organization so easily kept alive or reproduced that the movement could hardly be checked by any persecution short of the total annihilation which at length was actually the fate of many of the Swiss communities. The remnants of the Swiss Mennonites broke in 1620 into two parties, the stricter of which, the Ammanites or Upland Mennonites, were distinguished from the Lowland Mennonites by holding that excommunication of one party dissolved marriage, and by their rejection of buttons and the use of the razor. Their persecution lasted till 1710; a few congregations still remain and keep themselves quite distinct from Baptist bodies of more modern origin. In Germany the Mennonites are somewhat more numerous; more important are the German Mennonite colonies in southern Russia, brought thither in 1783 by the empress Catherine, which in turn have recently sent many emigrants to America. America indeed, and especially Pennsylvania, early became a refuge for the Mennonites of Switzerland, the Palatinate, and Holland, and is now the chief home of the body (175,000 in the United States and 25,000 in Canada). The oldest congregation is that of Germantown (since 1683); the most numerous of several divisions are the Old Mennonites, corresponding to the less strict of the Swiss sections.

All these communities in Europe and America are distinguished by an antique simplicity combined with antique prejudices, by indifference to the interests of the greater world, while at the same time their industry and self-concentration have made them generally well-to-do. Their religious type has varied very little in the course of centuries, as indeed is not surprising, their theology being ascetic rather than dogmatic or speculative. The Mennonites of Holland, on the other hand, have passed through an interesting and progressive history.

It was in Holland and the adjoining parts of Low Germany that the personal influence of Menno Simons (1492–1559) was mainly felt. He was originally a priest, and was pastor at his native place Witmarsum in Friesland from 1531 to 1536, when convictions long ripening in his mind compelled him to resign his cure. At this time the anti-pædo-baptist societies in the Low Countries were much agitated. The views which had just before received their political deathblow at Münster (see ANABAPTISTS) were not extinct, and even those who did not share them were by no means at one. Menno attached himself to the Obbenites, who held that on earth true Christians had no prospect but to suffer persecution, refused to use the sword, and looked for no millennium on earth. Menno became one of their elders, and by his wanderings among the scattered and oppressed communities, and especially by the natural eloquence and religious power of his numerous writings, did much to sustain the faith of his associates, to confirm the type of their religious life, and to prevent startling aberrations in doctrine or discipline. He was not an original thinker; but the love which all felt for the man, and which was kept alive for generations by his writings, gave him the place which the name of Mennonites expresses.

It may be ascribed to the influence of Menno's writings that the Dutch Mennonites, though for a time (since 1554) they broke into fractions on questions of discipline, and especially on the effect of excommunication upon marriage, never fell so far apart as regards the type of their religious life as to preclude the possibility of reunion. The Waterlanders in North Holland, who held the least strict doctrine of excommunication, soon moved farther in the direction of liberality, and exchanged the name Mennonites for that of Doopsgezinden (Baptist persuasion). In 1579 they refused to condemn any one for opinions, even on the incarnation, which the word of Scripture did not pronounce necessary to salvation. They aided William the Silent with money, and from 1581 to 1618 even accepted civil office. Meantime the stricter party had undergone various divisions, which, however, in 1627–32 were reunited on the basis of confessions essentially embodying Menno's teachings. They too had learned moderation, at least in their views of excommunication, and their antithesis to the state was softened since the cessation of persecution in 1581, but especially since in 1672 they were recognized as citizens. On the other hand, the adoption of a confession had deepened the separation between them and the liberal Doopsgezinden; but doctrine was never the fundamental principle of the Mennonite communities, confessionalism took no firm root, and the two sections gradually approached, and through a series of partial fusions became at length finally united when the Amsterdam congregations came together in 1801. The persuasion declined much in numbers in the 18th century; since then it has increased, and has now 127 congregations with nearly 50,000 members. The objection to hold civil office disappeared in 1795; that to carry arms in the war of freedom against Napoleon. Baptism on profession of faith and the refusal of the oath, tolerance in matters of doctrine without religious indifference, are the chief marks of the body, which in point of theological culture and general enlightenment, philanthropic zeal and social importance, has long stood very high.

Authorities.—The best life of Menno Simons is Cramer's, 1837. De Hoop Scheffer's article in Herzog-Plitt, *R. E.*, is excellent; only one point of consequence in his account seems to call for modification,—the book against John of Leyden, said to have been published before Menno joined the Obbenites, is almost certainly spurious. See Sepp, *Geschiedkundige Nasporingen*, i. (1872) p. 128 *sq.* The completest edition of Menno's works is that in folio, 1686. Many of them are known only in bad Dutch versions; Menno himself wrote in the "Oostersch" or East Sea Dialect of Low German. For the literature on the Mennonites in general, see De Hoop Scheffer, on whom the foregoing sketch is mainly dependent.

MENSHIKOFF, ALEXANDER DANILOVICH (1672–1729), born at Moscow on the 17th of November (o.s.) 1672, was the son of a poor man, who employed him to sell cakes about the streets of that city. In this humble occupation he attracted the attention of Lefort, one of Peter the Great's most active co-operators, who was pleased with his sprightliness, and took him into his service. Peter, soon afterwards

seeing the youth at Lefort's, was also delighted with him, and took him to be his page. Menshikoff soon became indispensable to the czar, assisting him in his workshop, and displaying signal bravery in the company of his master at the siege of Azoff. He formed one of the suite of Peter during his travels, and worked with him at Saardam and Deptford. Throughout his wars with the Swedes, Menshikoff was the companion of the czar, and greatly distinguished himself. For his gallantry at the battle of the Neva, on the 7th of May (o.s.) 1703, he received the order of St Andrew. In 1704 he was made general, and at the request of the czar created a prince of the Holy Roman Empire. His house on the Vasilii-Ostroff was magnificent; there ambassadors were received, and banquets were given gorgeous with gold and silver plate. Unfortunately there is a dark side to the picture, and the favourite was guilty of extortion to such an extent as to bring him under his master's censure. On the death of Peter the position of Menshikoff became very perilous; his successes had raised about him a host of enemies eager for his downfall. The Golitzins, Dolgoroukis, and all those who formed what may be called the Old Russian party, wished to proclaim the son of Alexis emperor. Those, however, whose aggrandizement was bound up with Peter's reforms—Menshikoff, Apraksin, Bontourlin, Goloffkin, and others—were in favour of giving the crown to Peter's widow, who accordingly ascended the throne as Catherine I. During her reign the influence of Menshikoff was unbounded, and he virtually governed the country; but the empress died in 1727, after a reign of two years. She had made a will, no doubt at the instigation of the favourite, to the effect that Peter, her grandson, was to be czar under the guardianship of Menshikoff, whose daughter Mary was to be married to the youthful sovereign. Under pretence of taking care of the young czar, Menshikoff caused him to be removed to his house and surrounded him with his creatures. He was now at the height of his power; foreign ambassadors remarked that even the great Peter himself was never feared so much. The young czar, however, showed no affection for Mary Menshikoff, and the girl was equally apathetic towards her betrothed, being in love with a member of the family of Sapieha at the time her father had forced her into the engagement. The Dolgoroukis used the aversion of the young prince to his *fiancée* as a means of creating dislike to the father. A chain of events was gradually leading to the downfall of the favourite. He was soon refused admittance to the summer palace, whither the young czar had retired. Next he was arrested, and so overpowered was he at his disgrace that he had an apoplectic stroke. In vain did he address letters both to the emperor and his sister. Shortly after, by order of the czar, the fallen magnate departed from St Petersburg, but more like a nobleman retiring to his estate than a culprit going into exile. The people regarded him with dislike, and most of them rejoiced over his fall. On his way a courier arrived with orders to take the czar's ring of betrothal from his daughter Mary and give her back her own, which had been worn by Peter II. Menshikoff was not permitted to pass through Moscow, but was conducted to Oranienburg, in the government of Riazan, and there placed under strict surveillance. Soon afterwards the whole family was banished to Siberia, and arrived at Berezoff towards the end of 1727. Menshikoff's wife died on the journey, and was buried near Kazan. On the arrival of the prisoners they were lodged in a wooden house, consisting of four rooms. But Menshikoff did not long endure the horrors of exile in this inclement region. According to Mannstein, he died (November 12, o.s., 1729) of an apoplectic stroke, because there was no one at Berezoff, as he himself remarked, who understood how to open a vein. The young czar ordered the release from exile of the two remaining children of Menshikoff,—his daughter Mary had died at Berezoff in the same year as her father,—and restored some of their property to them.

MENSHIKOFF, ALEXANDER SERGEIEVICH (1787–1869), great-grandson of Peter's favourite, born in 1787, entered the Russian service as attaché to the embassy at Vienna. He accompanied the emperor Alexander throughout his campaigns against Napoleon, and attained the rank of general, but retired from active service in 1823. He then devoted himself to naval matters, and put the Russian marine, which had fallen into decay during the reign of Alexander, on an efficient footing. On the outbreak of the Crimean War he was appointed commander-in-chief, and suffered a severe defeat at the Alma. On the death of the emperor Nicholas in 1855 he was recalled, ostensibly on account of failing health. He died in 1869.

MENSURATION

MENSURATION, or the art of measuring, involves the construction of measures, the methods of using them, and the investigation of rules by which magnitudes which it may be difficult or impossible to measure directly are calculated from the ascertained value of some associated magnitude. It is usual, however, to employ the term mensuration in the last of these senses; and we may therefore define it to be that department of mathematical science by which the various dimensions of bodies are calculated from the simplest possible measurements.

The determination of the lengths and directions of straight lines, including what are familiarly known as problems in heights and distances, generally depends on the solution of triangles, and will be discussed in the articles TRIGONOMETRY and SURVEYING. The remaining portions of the subject are the determinations of the lengths of curves, the areas of plane or other figures, and the volumes and surfaces of solids; and it is of mensuration as thus restricted that the present article will discuss some of the more important problems.

§ 1. *Units of Length, Area, and Volume.*—In measuring any magnitude we select some standard or "unit" to measure by. Thus in measuring length we take for unit an inch, a foot, or a yard. From the unit of length we derive the units of area and volume. Thus we define the unit of area to be the area of the square described upon the unit of length, and the unit of volume to be the volume of the cube whose edge is the unit of length or whose side is the unit of area. For example, if an inch be taken as the unit of length, the square whose side is 1 inch is the unit of area, and the cube whose edge is 1 inch is the unit of volume. The length of a line, the area of a surface, and the volume of a solid are then expressed by the numbers, whole or fractional, of units of length, area, and volume which they respectively contain. Hence, if l denote the linear unit, the length of a line which contains a units is al, or simply a since l is unity; similarly the area of a surface which contains b units of area is bm, or simply b, where m is the unit of area.

§ 2. *Commensurable and Incommensurable Magnitudes.*—When two magnitudes have a common measure, that is, when another magnitude can be found which is contained in each an exact number of times; they are said to be "commensurable." Thus a line $4\frac{1}{2}$ and another $3\frac{1}{2}$ inches

long are commensurable; for, if $\frac{1}{2}$ inch be taken as unit of length, the former contains the unit nine times and the latter seven times. If no common measure can be found, the two magnitudes are said to be "incommensurable." For instance, 1 and $\sqrt{2}$ have no common measure; for $\sqrt{2}=1\cdot4142\ldots$ an interminable decimal, and hence no unit, however small, can be found which will be contained in each an exact number of times. If, however, we take $\sqrt{2}=1\cdot4$, the error will be less than $\frac{1}{10}$; if $\sqrt{2}=1\cdot414$, the error will be less than $\frac{1}{1000}$, &c. Hence, by taking a sufficient number of figures, we can find a fraction which will differ from $\sqrt{2}$ by less than any assignable quantity, and therefore we can always find two commensurable magnitudes that will represent two incommensurable ones to any degree of accuracy we please. In what follows we need therefore only consider commensurable lines.

§ 3. *Area of a Rectangle.*—Let the side AB (fig. 1) contain a units and the side BC b units of length. If we divide AB into a equal parts, each equal to the unit of length, and similarly BC into b equal parts, and if through the points of division we draw lines parallel to the sides of the rectangle, these lines will divide the rectangle into a series of rectangles, each of which is the unit of area, since each is a square whose sides are of unit length. As we have a rows of these rectangles, and b in each row, the whole number of rectangles will be ab. Therefore

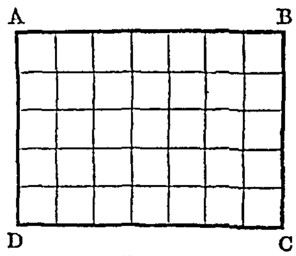


Fig. 1.

$$\text{area of ABCD}=ab \text{ units of area}$$
$$=ab$$

PART I.—PLANE FIGURES.

Section I.—Plane Figures contained by Straight Lines.

A. *The Rectangle.*

§ 4. Let ABCD (fig. 2) be a rectangle, and let AB=CD=a, BC=DA=b, AC=c, and the angle BAC=α; it is required to find its area. Since a rectangle is completely determined when two independent data, one of which at least is a length, are given connecting its parts, we can determine its area in the following cases.

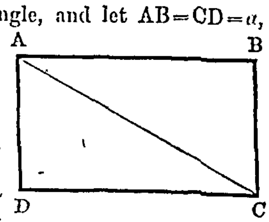


Fig. 2.

(α) *When its length* a *and its breadth* b *are given.*—It has already been proved (§ 3) that

$$\text{area of ABCD}=ab;$$

or the area of a rectangle is equal to its length multiplied by its breadth.

Example.—Let $a=12$ feet 6 inches and $b=9$ inches, then

$$\text{area of ABCD}=12\cdot5\times\cdot75=9\cdot375 \text{ square feet.}$$

If we make use of logarithms in the above calculation we have

$$\log\text{area}=\log a+\log b.$$
$$\log a=\log 12\cdot5\ =1\cdot0969100$$
$$\log b=\log\ \ \cdot75=\bar{1}\cdot8750613$$
therefore $\qquad\log\text{area}=\ \cdot9719713;$
hence $\qquad\text{area}=9\cdot375.$

(β) *When a side* a *and the diagonal* c *are given.*—By Euclid i. 47 we have

$$b^2=c^2-a^2, \text{ or } b=\sqrt{c^2-a^2},$$
therefore $\qquad\text{area of ABCD}=ab=a\sqrt{c^2-a^2};$
or $\qquad\log\text{area}=\log a+\frac{1}{2}\log(c+a)+\frac{1}{2}\log(c-a).$

Example.—Let $a=238$ and $c=456$, then

$$\log a=\ \log 238=2\cdot3765770$$
$$\tfrac{1}{2}\log(c+a)=\tfrac{1}{2}\log 694=1\cdot4206797$$
$$\tfrac{1}{2}\log(c-a)=\tfrac{1}{2}\log 218=1\cdot1692282$$
therefore $\qquad\log\text{area}=4\cdot9664849;$
hence $\qquad\text{area}=92573\cdot1.$

(γ) *When a side* a *and* α *its inclination to the diagonal are given.*—Since

$$\frac{b}{a}=\tan\alpha,\quad b=a\tan\alpha,$$
and therefore $\qquad\text{area of ABCD}=ab=a^2\tan\alpha;$
or $\qquad\log\text{area}=2\log a+\text{L}\tan\alpha-10.$

Example.—Let $a=36$ and $\alpha=32°\ 25'\ 15''$, then

$$2\log a=2\log 36=\ 3\cdot1126050$$
$$\text{L}\tan\alpha=\text{L}\tan 32°\ 25'\ 15''=\ 9\cdot8028622$$
therefore $\qquad\log\text{area}=12\cdot9154672-10=2\cdot9154672;$
hence $\qquad\text{area}=823\cdot127.$

(δ) *When the diagonal* c *and* α *its inclination to either of the sides are given.*—We have

$$a=c\cos\alpha,\text{ and } b=c\sin\alpha,$$
therefore $\text{area of ABCD}=ab=c^2\sin\alpha\cos\alpha=\frac{1}{2}c^2\sin 2\alpha;$
or $\qquad 2\text{area}=c^2\sin 2\alpha,$
and hence $\qquad\log 2\text{area}=2\log c+\text{L}\sin 2\alpha-10.$

§ 5. A square being a rectangle whose sides are equal, we can at once determine its area. When one datum, which must be a length, is given the square is completely determined, and hence we have only two cases to consider.

(α) *When the side is given.*—From § 4, α, we have at once

$$\text{area of square}=ab=a\times a=a^2.$$

(β) *When the diagonal* c *is given.*—From § 4, β, we have

$$a^2+a^2=c^2,\text{ or } a^2=\tfrac{1}{2}c^2;$$
hence $\qquad\text{area of square}=a^2=\frac{1}{2}c^2,\text{ or } 2\text{area}=c^2;$
and therefore $\qquad\log 2\text{area}=2\log c.$

B. *Right-angled Triangles.*

§ 6. The diagonal of every rectangle divides it into two equivalent right-angled triangles (Eucl. i. 34), and hence the area of the right-angled triangle ABC (fig. 2) is equal to half the area of the corresponding rectangle ABCD.

C. *Triangles Generally.*

§ 7. In every triangle there are six elements to be considered, namely, the three sides and the three angles. If any three of these six be given, provided one is a length, the triangle is completely determined, and hence its area can be found.

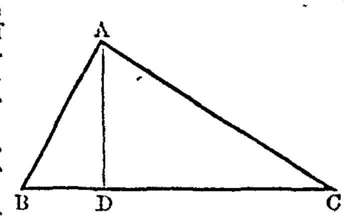


Fig. 3.

§ 8. *Length of Perpendiculars of a Triangle.*—In the triangle ABC (fig. 3) let BC=a, CA=b, AB=c, AD the perpendicular from A on BC=h, BD=x, and CD=y.

Since BDA and CDA are right angles, we have

$$c^2=x^2+h^2,\text{ and } b^2=y^2+h^2,$$
and therefore
$$b^2-c^2=y^2-x^2=(y+x)(y-x)=a(y-x);$$
whence $\qquad y-x=\dfrac{b^2-c^2}{a}.$

But $y+x=a$, and, by solving these equations, we obtain

$$y=\frac{b^2+a^2-c^2}{2a}.$$

Again

$$h^2=b^2-y^2=b^2-\left(\frac{b^2+a^2-c^2}{2a}\right)^2=\frac{(2ab)^2-(b^2+a^2-c^2)^2}{4a^2}$$
$$=\frac{(a+b+c)(b+c-a)(c+a-b)(a+b-c)}{4a^2};$$
hence $\qquad h=\dfrac{1}{2a}\sqrt{(a+b+c)(b+c-a)(c+a-b)(a+b-c)}.$

Now let $a+b+c=2s$, then $b+c-a=2(s-a)$, $c+a-b=2(s-b)$, and $a+b-c=2(s-c)$.

Therefore, on substituting and reducing, we obtain

$$h=\frac{2}{a}\sqrt{s(s-a)(s-b)(s-c)}.$$

Similarly the perpendiculars from B and C on the opposite sides are respectively

$$\frac{2}{b}\sqrt{s(s-a)(s-b)(s-c)},\text{ and } \frac{2}{c}\sqrt{s(s-a)(s-b)(s-c)}.$$

§ 9. We now proceed to investigate formulæ for the area of a triangle in the following important cases.

(α) *When the base* a *and the altitude* h *are given.*—Since a

triangle is equel to half a rectangle of the same base and altitude, we have at once

$$\text{area ABC} = \tfrac{1}{2}ah.$$

Example.—Let $a=40$ chains and $h=14{\cdot}52$ chains, then

$$\text{area} = \tfrac{1}{2}\times 40\times 14{\cdot}52 = 290{\cdot}4 \text{ square chains.}$$

(β) *When two sides* a *and* c *and the included angle* B *are given.*—From fig. 3 $\frac{h}{c} = \sin B$, and therefore $h = c\sin B$;

hence $\quad \text{area} = \tfrac{1}{2}ah = \tfrac{1}{2}ac\sin B$;

or $\quad \log 2\text{area} = \log a + \log c + \text{L}\sin B - 10.$

Example.—Let $a=40$, $c=30$, and $B=30°$, then

$$\text{area} = \tfrac{1}{2}ac\sin B = \tfrac{1}{2}\times 40\times 30\times\tfrac{1}{2} = 300.$$

(γ) *When the three sides* a, b, c *are given.*—From § 8

$$h = \frac{2}{a}\sqrt{s(s-a)(s-b)(s-c)},$$

and therefore

$$\text{area} = \tfrac{1}{2}ah = \tfrac{1}{2}a\times\frac{2}{a}\sqrt{s(s-a)(s-b)(s-c)} = \sqrt{s(s-a)(s-b)(s-c)};$$

or $\quad \log\text{area} = \tfrac{1}{2}\{\log s + \log(s-a) + \log(s-b) + \log(s-c)\}.$

Since $2s = a+b+c$, we have

$$\text{area of triangle} = \tfrac{1}{4}\sqrt{2(a^2b^2+b^2c^2+c^2a^2)-(a^4+b^4+c^4)}.$$

Example 1.—Let $a=13$, $b=14$, and $c=15$, then

$$s = \tfrac{1}{2}(13+14+15) = 21,\quad s-a = 21-13 = 8,$$
$$s-b = 21-14 = 7,\ \text{ and } s-c = 21-15 = 6;$$

therefore $\quad \text{area} = \sqrt{21\times 8\times 7\times 6} = 84.$

Example 2.—Let $a=255$, $b=238$, and $c=221$, then

$$\begin{aligned} \log s &= \log 357 = 2{\cdot}5526682 \\ \log(s-a) &= \log 102 = 2{\cdot}0086002 \\ \log(s-b) &= \log 119 = 2{\cdot}0755470 \\ \log(s-c) &= \log 136 = 2{\cdot}1335389 \end{aligned}$$

therefore $\quad \log\text{area} = \tfrac{1}{2}(8{\cdot}7703543) = 4{\cdot}3851771$;

hence $\quad \text{area} = 24276.$

(δ) *When any two angles* B *and* C *and the adjacent side* a *are given.*—Since

$$\frac{c}{a} = \frac{\sin C}{\sin A},\quad c = \frac{a\sin C}{\sin A},$$

and therefore (by β)

$$\text{area} = \tfrac{1}{2}ac\sin B = \frac{a^2\sin B\sin C}{2\sin A},\quad \text{where } A = 180° - (B+C),$$

or $\quad \log 2\text{area} = 2\log a + \text{L}\sin B + \text{L}\sin C + \text{L}\operatorname{cosec} A - 30.$

Since all the angles of a triangle are given when any two are given, we can find the area of a triangle when any two angles and any one side are given. Thus, when A, B, and c are given, we know C also, and the problem reduces to a case of the preceding.

(ε) *When the three medians* α, β, γ *are given.*—If a, b, c be the three sides of a triangle, and α, β, γ the three medians, *i.e.*, the lines drawn from the angles to the middle points of the opposite sides, then by well-known geometrical propositions we have

$$4(\alpha^2+\beta^2+\gamma^2) = 3(a^2+b^2+c^2),$$
$$16(\alpha^2\beta^2+\beta^2\gamma^2+\gamma^2\alpha^2) = 9(a^2b^2+b^2c^2+c^2a^2),$$

and $\quad 16(\alpha^4+\beta^4+\gamma^4) = 9(a^4+b^4+c^4).$

Now (§ 9, γ)

area of triangle $= \tfrac{1}{4}\sqrt{2(a^2b^2+b^2c^2+c^2a^2)-(a^4+b^4+c^4)}$,

therefore $= \tfrac{1}{3}\sqrt{2(\alpha^2\beta^2+\beta^2\gamma^2+\gamma^2\alpha^2)-(\alpha^4+\beta^4+\gamma^4)}$.

D. *Parallelograms.*

§ 10. The opposite sides and angles of a parallelogram being equal, three independent data, one of which at least is a length, are necessary and sufficient to determine it completely.

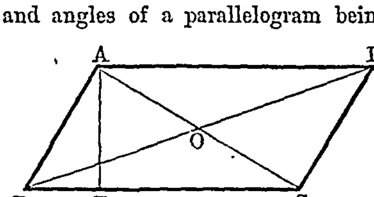


Fig. 4.

In the parallelogram ABCD (fig. 4) let $BC = DA = a$, $AB = CD = b$, $AC = c$, $AE = h$, the angle $ABC = \alpha$ and $AOD = \beta$.

Since the diagonal AC divides the parallelogram into two equivalent triangles, we obtain

(α) $\quad$ area of ABCD = 2 area of triangle ABC $= 2\times\tfrac{1}{2}\,a\times h$ (§ 9, α) $= ah$;

(β) area of ABCD = 2 area ABC $= 2\times\tfrac{1}{2}ab\sin\alpha$ (§ 9, β) $= ab\sin\alpha$;

or $\quad \log\text{area} = \log a + \log b + \text{L}\sin\alpha - 10$;

(γ) $\quad$ area of ABCD = 2 area ABC = 2(ABO + CBO)

$$= 2\{\tfrac{1}{2}\text{BO.AO}\sin\text{AOB} + \tfrac{1}{2}\text{BO.CO}\sin\text{COB}\} = 2\{\tfrac{1}{2}\text{BO.AC}\sin\beta\}$$
$$= \tfrac{1}{2}\text{BD.AC}\sin\beta = \tfrac{1}{2}cd\sin\beta,$$

or $\quad \log 2\text{area} = \log c + \log d + \text{L}\sin\beta - 10.$

§ 11. If the parallelogram be *equiangular* (a rectangle), $c=d$, and area $= \tfrac{1}{2}c^2\sin\beta$. If it be *equilateral* (a rhombus), $\beta = 90°$, and area $= \tfrac{1}{2}cd$. If it be both *equiangular* and *equilateral* (a square), $c=d$ and $\beta=90°$, and area $= \tfrac{1}{2}c^2$ as before (§ 5, β).

E. *Trapeziums.*

§ 12. To determine a trapezium completely four data are necessary and sufficient.

In the trapezium ABCD (fig. 5) let $BC = a$, $CD = b$, $DA = c$, $AB = d$,

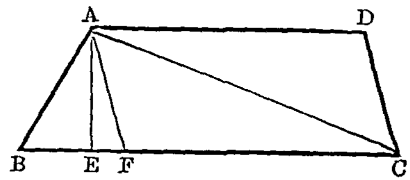


Fig. 5.

and AE perpendicular to $BC = h$, and draw AF parallel to CD, then

(α) $\quad$ area ABCD = area ABC + area ADC

$$= \tfrac{1}{2}ah + \tfrac{1}{2}ch$$
$$= \tfrac{1}{2}(a+c)h;$$

or the area is equal to half the sum of the parallel sides multiplied by the perpendicular between them.

Again, area of ABF $= \tfrac{1}{2}\text{BF}\times\text{AE}$ (§ 9, α) $= \tfrac{1}{2}(a-c)h$,

also $\quad$ area of ABF $= \sqrt{s(s-\text{AB})(s-\text{BF})(s-\text{FA})}$,

where $\quad 2s = \text{AB} + \text{BF} + \text{FA}$;

hence $\quad h = \dfrac{2}{a-c}\sqrt{s(s-\text{AB})(s-\text{BF})(s-\text{FA})}$, therefore

(β) $\quad$ area of ABCD $= \tfrac{1}{2}(a+c)h = \dfrac{a+c}{a-c}\sqrt{s(s-\text{AB})(s-\text{BF})(s-\text{FA})}$

$$= \tfrac{1}{4}\frac{a+c}{a-c}\sqrt{(-a+b+c+d)(a+b-c-d)(a+b-c+d)(a-b-c+d)},$$

since $\quad AB = d$, $BF = a-c$, and $FA = CD = b$.

Thus we can find the area of a trapezium in terms of its sides.

§ 13. If $c=0$, ABCD becomes a triangle, and its area

$$= \tfrac{1}{4}\sqrt{(-a+b+d)(a+b-d)(a+b+d)(a-b+d)}.$$

Again, if $c=a$, then also $b=d$, and ABCD becomes a parallelogram, and its area takes the indeterminate form $\frac{0}{0}$, as it should do, since four sides do not completely determine a parallelogram.

F. *Quadrilaterals Generally.*

§ 14. A quadrilateral is completely determined when five independent data are given. We consider the following cases.

(α) *When any diagonal and the perpendiculars on it from the opposite vertices are given.*

The quadrilateral ABCD (fig. 6) = ABD + BCD

$$= \tfrac{1}{2}\text{BD.AE} + \tfrac{1}{2}\text{BD.CF}$$
$$= \tfrac{1}{2}\text{BD(AE + CF)};$$

or the area is equal to half the product of the diagonal and the sum of the perpendiculars.

If the diagonal BD fall without the figure, as in the concave quadrilateral ABCD (fig. 7), then it is clear that

area ABCD $= \tfrac{1}{2}$BD(AE − CF).

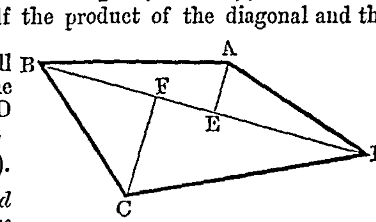


Fig. 6.

(β) *When the diagonals and their included angle are given.*—In the quadrilateral ABCD (fig. 8, p. 16) let $BD = h$, $AC = k$, and angle $DEA = \alpha$, then

$$\begin{aligned} \text{ABCD} &= \text{ABD} + \text{BCD} \\ &= \tfrac{1}{2}\text{BD.AE}\sin\alpha + \tfrac{1}{2}\text{BD.CE}\sin\alpha \ (\S\ 10.\ \gamma) \\ &= \tfrac{1}{2}h(\text{AE} + \text{CE})\sin\alpha \\ &= \tfrac{1}{2}hk\sin\alpha; \end{aligned}$$

or the area is equal to the product of the diagonals and the sine of their contained angle.

The same result holds when one of the diagonals falls without the quadrilateral, as in fig. 7, as the reader can easily verify.

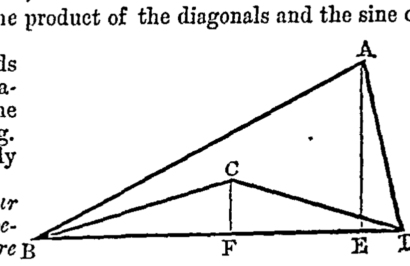


Fig. 7.

(γ) *When the four sides and the angle between the diagonals are given.*—If a, b, c, d be the sides and α the angle between the diagonals it can easily be shown that

$$\text{area of quadrilateral} = \tfrac{1}{4}(a^2-b^2+c^2-d^2)\tan\alpha.$$

(δ) *When the four sides are given and the opposite angles are supplementary.*—In fig. 8 let $AB=a$ $BC=b$, $CD=c$, $DA=d$, $AC=h$, angle $ABC=\alpha$, angle $CDA=\beta$, and let $\alpha+\beta=180°$, then

$$\text{area of } ABCD = ABC + ADC = \tfrac{1}{2}ab\sin\alpha + \tfrac{1}{2}cd\sin\beta.$$

But

$$\sin\beta = \sin(180° - \alpha) = \sin\alpha,$$

therefore

$$\text{area of } ABCD = \tfrac{1}{2}(ab+cd)\sin\alpha.$$

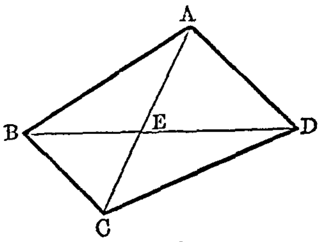


Fig. 8.

This gives us the area of the quadrilateral in terms of the four sides and one angle.

Again we have

$$a^2+b^2-2ab\cos\alpha = h^2 = c^2+d^2-2cd\cos\beta = c^2+d^2+2cd\cos\alpha,$$

therefore $\cos\alpha = \dfrac{a^2+b^2-c^2-d^2}{2(ab+cd)}$, and hence

$$1+\cos\alpha = \frac{(a+b+c-d)(a+b-c+d)}{2(ab+cd)}, \text{ and}$$

$$1-\cos\alpha = \frac{(c+d+a-b)(c+d-a+b)}{2(ab+cd)}.$$

From this we obtain

$$\sin^2\alpha = (1+\cos\alpha)(1-\cos\alpha)$$
$$= \frac{(b+c+d-a)(c+d+a-b)(d+a+b-c)(a+b+c-d)}{4(ab+cd)^2}.$$

Now let $a+b+c+d=2s$,

then $\tfrac{1}{2}(ab+cd)\sin\alpha = \sqrt{(s-a)(s-b)(s-c)(s-d)}$;

therefore area of $ABCD = \sqrt{(s-a)(s-b)(s-c)(s-d)}$,

or $\log \text{area} = \tfrac{1}{2}\{\log(s-a)+\log(s-b)+\log(s-c)+\log(s-d)\}$.

If $d=0$, the quadrilateral becomes a triangle, and its area is $\sqrt{(s-a)(s-b)(s-c)s}$ as before. In extracting the square root of $\sin\alpha$ we take the positive sign, since the angle α is less than two right angles.

G. *Regular Polygons.*

§ 15. Since a regular polygon is both equilateral and equiangular, a circle can be inscribed within it and also described about it, and thus the n straight lines drawn from the common centre of the two circles to the n vertices of the polygon divide it into n triangles equal in every respect. Therefore the area of the polygon is equal to n times the area of any one of these triangles.

§ 16. *Radius of Inscribed and Circumscribed Circles.*—Let AB (fig. 9) $=a$ be a side of a regular polygon of n sides; let C be the centre of the inscribed and circumscribed circles, $CD=r$ the radius of the former, and $CE=R$ the radius of the latter. The angle ACB is evidently equal to the nth part of four right angles, that is

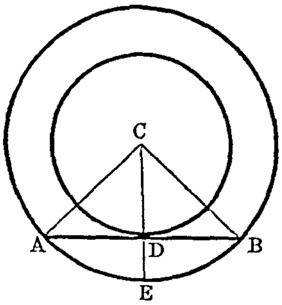


Fig. 9.

$$ACB = \frac{360°}{n}, \text{ and } ACD = \tfrac{1}{2}ACB = \frac{180°}{n}.$$

Now $AD = \dfrac{a}{2} = CD\tan ACD = r\tan\dfrac{180°}{n}$,

and $AD = \dfrac{a}{2} = AC\sin ACD = R\sin\dfrac{180°}{n}$;

therefore $r = a\times\tfrac{1}{2}\cot\dfrac{180°}{n}$,

and $R = a\times\tfrac{1}{2}\operatorname{cosec}\dfrac{180°}{n}$.

§ 17. *Perimeter of Polygon.*—The perimeter of the polygon of n sides is na, *i.e.*, $2nr\tan\dfrac{180°}{n}$, or $2nR\sin\dfrac{180°}{n}$.

From this it follows that the perimeters of the inscribed and circumscribed regular polygons of n sides of a circle of radius r are

$$2nr\sin\frac{180°}{n} \text{ and } 2nr\tan\frac{180°}{n} \text{ respectively.}$$

§ 18. *Area of Polygon.*

(α) *In terms of* r.—The area of polygon

$$= nACB = nAD\,.\,CD = n\times r^2\tan\frac{180°}{n}.$$

(β) *In terms of* R.—The triangle ACB

$$= \tfrac{1}{2}AC\,.\,CB\sin ACB = \tfrac{1}{2}R^2\sin\frac{360°}{n},$$

and therefore area of polygon $= \tfrac{1}{2}nR^2\sin\dfrac{360°}{n}$.

(γ) *In terms of* a.—The triangle ACB

$$= \tfrac{1}{2}AB\,.\,CD = \frac{a}{2}\times r = \frac{a}{2}\times\tfrac{1}{2}a\cot\frac{180°}{n} = \frac{a^2}{4}\cot\frac{180°}{n},$$

and therefore area of polygon $= a^2\times\dfrac{n}{4}\cot\dfrac{180°}{n}$,

or $\log 4\,\text{area} = \log n + L\cot\dfrac{180°}{n} + 2\log a - 10$.

From α and β it follows that the areas of the inscribed and circumscribed regular polygons of n sides of a circle of radius r are

$$\tfrac{1}{2}nr^2\sin\frac{360°}{n} \text{ and } nr^2\tan\frac{180°}{n} \text{ respectively.}$$

§ 19. In the formula (§ 18, γ) for the area of a polygon, the factor $\dfrac{n}{4}\cot\dfrac{180°}{n}$ has a definite value for every value of n, and hence, if we find its value once for all for a large number of values of n, and tabulate the results, we can find the area of a regular polygon of n sides by multiplying the square of its side by the appropriate tabular value.

Again, if $a=1$ we have

$$r = \tfrac{1}{2}\cot\frac{180°}{n} \text{ and } R = \tfrac{1}{2}\operatorname{cosec}\frac{180°}{n};$$

and thus we obtain in a similar manner the radius of the inscribed and circumscribed circles by multiplying the side by the appropriate tabular value of $\tfrac{1}{2}\cot\dfrac{180°}{n}$ and $\tfrac{1}{2}\operatorname{cosec}\dfrac{180°}{n}$ respectively.

§ 20. The following table contains the values of $\dfrac{n}{4}\cot\dfrac{180°}{n}$ and their logarithms, and the values of $\tfrac{1}{2}\cot\dfrac{180°}{n}$ and $\tfrac{1}{2}\operatorname{cosec}\dfrac{180°}{n}$ for all values of n from 3 to 12.

n	$\frac{n}{4}\cot\frac{180°}{n}$	Logarithms.	$\frac{1}{2}\cot\frac{180°}{n}$	$\frac{1}{2}\operatorname{cosec}\frac{180°}{n}$
3	0·4330127	$\bar{1}$·6365006	0·28867	·57735
4	1·0000000	0·0000000	0·50000	·70710
5	1·7204774	0·2356490	0·68819	·85065
6	2·5980762	0·4146519	0·86602	1·0000
7	3·6339124	0·5603745	1·0383	1·1523
8	4·8284271	0·6380568	1·2071	1·3065
9	6·1818242	0·7911166	1·3737	1·4619
10	7·6942088	0·8861610	1·5388	1·6180
11	9·3656407	0·9715375	1·7028	1·7747
12	11·1961524	1·0490688	1·8660	1·9318

Let A denote the area of a polygon of n sides and A′ the corresponding tabular value of $\dfrac{n}{4}\cot\dfrac{180°}{n}$, then

$$A = a^2A',$$

or

$$\log A = 2\log a + \log A'.$$

H.—*Length of the Radius of the Inscribed, Escribed, and Circumscribed Circles of a Triangle.*

§ 21. (α) *Radius of Inscribed Circle.*—Let O (fig. 10) be the centre of the circle inscribed in the triangle ABC and touching the sides in D, E, and F. Join OA, OB, and OC. The angles at D, E, F are right angles (Eucl. iii. 18). Let $BC=a$, $CA=b$, $AB=c$, and $OD=OE=OF=r$.

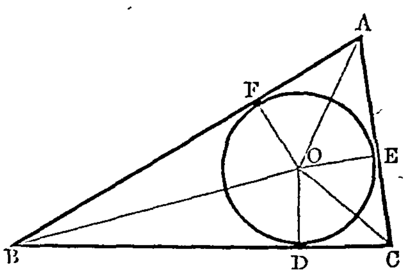


Fig. 10.

Now $ABC = BOC + COA + AOB$

$$= \tfrac{1}{2}ar + \tfrac{1}{2}br + \tfrac{1}{2}cr = \tfrac{1}{2}(a+b+c)r = rs;$$

whence $r = \dfrac{\text{area of } ABC}{s} = \dfrac{\sqrt{s(s-a)(s-b)(s-c)}}{s}$.

(β) *Radius of Escribed Circles.*—Let $OD=OE=OF=r_a$, then

$$ABC = ACO + ABO - BOC$$
$$= \tfrac{1}{2}br_a + \tfrac{1}{2}cr_a - \tfrac{1}{2}ar_a = \tfrac{1}{2}(b+c-a)r_a = r_a(s-a);$$

and $r_a = \dfrac{\text{area of } ABC}{s-a} = \dfrac{\sqrt{s(s-a)(s-b)(s-c)}}{s-a} = \sqrt{\dfrac{s(s-b)(s-c)}{s-a}}$.

Similarly

$$r_b = \sqrt{\frac{s(s-a)(s-c)}{s-b}} \text{ and } r_c = \sqrt{\frac{s(s-a)(s-b)}{s-c}}.$$

(γ) *Radius of Circumscribed Circle.*—Let AD (fig. 12) $=p$ the perpendicular from A on the side BC, and AE $=2$R the diameter

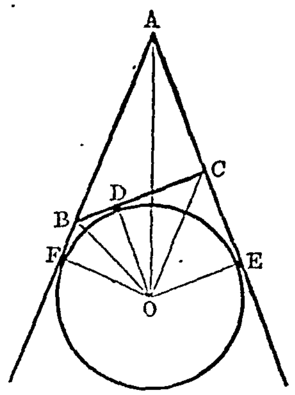


Fig. 11.

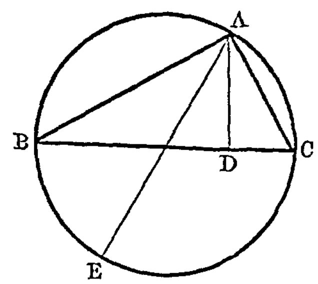


Fig. 12.

of the circle, then (Eucl. vi. C) we have

$$2R\times p=b\times c,$$

therefore

$$2R\times ap=abc.$$

Now $ap=2\Delta$, where Δ denotes the area of ABC;

hence

$$R=\frac{abc}{4\Delta}=\frac{abc}{4\sqrt{s(s-a)(s-b)(s-c)}}.$$

Example.—Let $a=13$, $b=14$, and $c=15$; then r will be found to be 4, r_a $10\frac{1}{2}$, r_b 12, r_c 14, and R $8\frac{1}{8}$.

Section II.—Plane Figures contained by Curved Lines.

A. *The Circle.*

§ 22. *Circumference of a Circle.*—If we inscribe in any circle a regular polygon of n sides, and also circumscribe a regular polygon of the same number of sides, it is clear that the perimeter of the circle is intermediate between the perimeters of the inscribed and circumscribed polygons, and that the difference between the perimeters of the inscribed and circumscribed polygons can be made as small as we please by sufficiently increasing n. A similar statement holds with reference to the areas of the circle and the inscribed and circumscribed polygons. With the above assumptions it is easily proved that the circumference of a circle bears a constant ratio to its diameter. Hence we have

$$\text{Circumference}=C=\text{constant}\times\text{radius}=\text{constant}\times r.$$

It is usual to denote this constant by 2π, and therefore

$$C=2\pi r=\pi d,\ \text{where } d \text{ is the diameter of the circle.}$$

§ 23. *Numerical Value of* π.—The constant π being, as can be easily proved, an interminable decimal, we can only approximate to its value, but this we can do to any degree of accuracy we please. If s and σ denote respectively a side of the inscribed and circumscribed polygons of n sides, and s' and σ' a side of the inscribed and circumscribed polygons of $2n$ sides, it can easily be shown that

$$(\alpha)\ \sigma=\frac{rs}{\sqrt{r^2-(\frac{1}{2}s)^2}},\qquad(\beta)\ s'^2=2r\left\{r-\sqrt{r^2-(\tfrac{1}{2}s)^2}\right\},$$

$$(\gamma)\ \sigma'=\frac{rs'}{\sqrt{r^2-(\frac{1}{2}s')^2}},$$

where r is the radius of the circle.

If we take $r=\frac{1}{2}$ we find, by means of these formulæ, and by assuming the value of s when $n=6$, that the perimeter of inscribed polygon of 96 sides $=3·140$ . . . . , and the perimeter of circumscribed polygon of 96 sides $=3·142$. . . .

From this we learn that the circumference of the circle, in this case π, is greater than 3·140 . . . . and less than 3·142 . . . . , and therefore as far as the second place of decimals

$$\pi=3·14.$$

By taking greater and greater values of n we obtain closer and closer approximations to π.

The preceding method for approximating to the value of π is the simplest afforded by elementary geometry, and is also the oldest; but better and more rapid methods are furnished by the higher mathematics. The calculation of π has been carried to 707 places of decimals, the following being the first 20 figures in the result:—

$$3·14159265358979323846.$$

For all practical purposes it is sufficient to take

$$\pi=3·14159\ \text{or}\ \frac{355}{133}.$$

§ 24. The following table contains the functions of π that are of most frequent occurrence in mensuration:—

	Number.	Logarithm.		Number.	Logarithm.
π	3·1415927	0·4971499	π^2	9·8696044	0·9942997
2π	6·2831853	0·7981799			
4π	12·5663706	1·0992099	$\frac{1}{6\pi^2}$	0·0168869	$\bar{2}$·2275490
$\frac{1}{2}\pi$	1·5707963	0·1961199			
$\frac{1}{3}\pi$	1·0471976	0·0200286	$\sqrt{\pi}$	1·7724539	0·2485750
$\frac{1}{4}\pi$	0·7853982	$\bar{1}$·8950899			
$\frac{1}{6}\pi$	0·5235988	$\bar{1}$·7189986	$\sqrt[3]{\pi}$	1·4645919	0·1657166
$\frac{1}{8}\pi$	0·3926991	$\bar{1}$·5940599			
$\frac{1}{12}\pi$	0·2617994	$\bar{1}$·4179686	$\frac{1}{\sqrt{\pi}}$	0·5641896	$\bar{1}$·7514251
$\frac{4}{3}\pi$	4·1887902	0·6220886			
$\frac{\pi}{180}$	0·0174533	$\bar{2}$·2418774	$\frac{2}{\sqrt{\pi}}$	1·1283792	0·0524551
$\frac{1}{\pi}$	0·3183099	$\bar{1}$·5028501	$\frac{1}{2\sqrt{\pi}}$	0·2820948	$\bar{1}$·4503951
$\frac{4}{\pi}$	1·2732395	0·1049101	$\sqrt[3]{\frac{6}{\pi}}$	1·2407010	0·0936671
$\frac{1}{4\pi}$	0·0795775	$\bar{2}$·9007901	$\sqrt[3]{\frac{3}{4\pi}}$	0·6203505	$\bar{1}$·7926371
$\frac{180}{\pi}$	57·2957795	1·7581226	$\log_e\pi$	1·1447299	0·0587030

§ 25. *Units of Angular Measurement.*—In measuring lines we select some line of constant length as the standard or unit; similarly in measuring angles we require to take some angle of constant magnitude as unit angle. The right angle is by its nature the simplest unit angle, but, for convenience, we take the $\frac{1}{90}$th part of a right angle for unit, and call it a degree, which is subdivided into sixty equal parts called minutes, and these again into sixty equal parts called seconds. For theoretical purposes we define the unit angle to be *the angle subtended at the centre of a circle by an arc equal to the radius.* This angle we call a "radian." In many treatises the radian measure of an angle is called the circular measure.

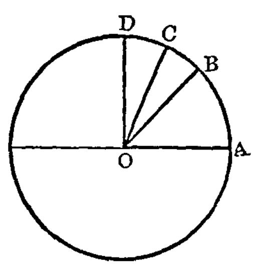


Fig. 13.

§ 26. *The radian is a constant angle.*—Let OA (fig. 13) $=$ arc AB $=r$, then AOB $=$ radian, and let AOD $=90°$; then

$$\text{arc AD}=\tfrac{1}{4}\times2\pi r=\tfrac{1}{2}\pi r;$$

and, since angles at the centre of a circle are proportional to the arcs on which they stand (Eucl. vi. 33),

$$\frac{\text{number of degrees in radian AOB}}{\text{number of degrees in AOD}}=\frac{AB}{AD}=\frac{r}{\frac{1}{2}\pi r}=\frac{2}{\pi};$$

therefore number of degrees in radian

$$=90°\times\frac{2}{\pi}=57°·2957795=\text{constant.}$$

§ 27. *Number of Radians in any Angle.*—Let AOC (fig. 13) be any angle, AOB the radian, and AC $=s$; then

$$\frac{\text{number of radians in AOC}}{\text{one radian}}=\frac{AC}{AB}=\frac{s}{r};$$

therefore number of radians in AOC $=\dfrac{s}{r}$.

If AOC $=90°$, then $s=\frac{1}{2}\pi r$, and number of radians $=\frac{1}{2}\pi$; there are thus π radians in two and 2π in four right angles.

When $r=1$ we have number of radians $=s$, and hence in some treatises for the number of radians in an angle we find the length of the arc given.

§ 28. *To transfer from degrees to radians and conversely.*—Let x denote the number of degrees in an angle, and θ the number of radians in the same, then, since $\dfrac{x}{180°}=\dfrac{\theta}{\pi}$,

$$(\alpha)\ \theta=\frac{\pi x°}{180},\quad(\beta)\ x°=\frac{180}{\pi}\theta.$$

§ 29. The following table contains the values of θ for values of x up to 180°, and also for minutes and seconds.

Degrees.	Radian.	Degrees.	Radian.	Degrees.	Radian.	Minutes.	Radian. ·0	Seconds.	Radian. ·000
1	·0174533	61	1·0646508	121	2·1118484	1	002909	1	0048
2	·0349066	62	1·0821041	122	2·1293017	2	005818	2	0097
3	·0523599	63	1·0995574	123	2·1467550	3	008727	3	0145
4	·0698132	64	1·1170107	124	2·1642083	4	011636	4	0194
5	·0872665	65	1·1344640	125	2·1816616	5	014544	5	0242
6	·1047198	66	1·1519173	126	2·1991149	6	017453	6	0291
7	·1221730	67	1·1693706	127	2·2165682	7	020362	7	0339
8	·1396263	68	1·1868239	128	2·2340214	8	023271	8	0388
9	·1570796	69	1·2042772	129	2·2514747	9	026180	9	0436
10	·1745329	70	1·2217305	130	2·2689280	10	029089	10	0485
20	·3490659	80	1·3962634	140	2·4434610	20	058178	20	0970
30	·5235988	90	1·5707963	150	2·6179939	30	087266	30	1454
40	·6981317	100	1·7453293	160	2·7925268	40	116355	40	1939
50	·8726646	110	1·9198622	170	2·9670597	50	145444	50	2424
60	1·0471976	120	2·0943951	180	3·1415927	60	174533	60	2909

As an example of the use of this table we proceed to find the value of θ when $x = 68^\circ\ 45'\ 17''\cdot 8$.

$$\begin{aligned} \text{When } x &= 68^\circ & \theta &= 1\cdot 1868239\,, \\ x &= 40' & \theta &= \cdot 0116355\,, \\ x &= \ 5' & \theta &= \cdot 0014544\,, \\ x &= 10'' & \theta &= \cdot 0000485\,, \\ x &= \ 7'' & \theta &= \cdot 0000339\,, \\ \text{and when } x &= 0''\cdot 8 & \theta &= \underline{\cdot 0000039}\,, \\ \text{therefore when } x &= 68^\circ\ 45'\ 17''\cdot 8 & \theta &= \overline{1\cdot 2000001}\,. \end{aligned}$$

§ 30. Combining the results of §§ 27 and 28 we obtain

$$(\alpha) \quad \theta = \frac{s}{r}, \text{ and } x = \frac{180}{\pi} \cdot \frac{s}{r}\,;$$

$$(\beta) \quad r = \frac{s}{\theta} = \frac{180}{\pi} \cdot \frac{s}{x}\,;$$

$$(\gamma) \quad s = r\theta = \frac{\pi}{180} \cdot rx\,.$$

§ 31. *Length of Arcs of Circles.*—The following are the more important cases:—

(α) *In terms of the chord of the arc and the radius of the circle.*—Let AB (fig. 14) $= 2c$, AC $= r$, and AEB $= s$, then

$$\text{AD} = \tfrac{1}{2}\text{AB} = c = r \sin \tfrac{1}{2}\text{C}, \text{ whence C is known, and therefore}$$
the arc s is found (§ 30, γ).

(β) *In terms of the height of the arc and the radius of the circle.*—Let DE $= h =$ height of arc, then

$$\text{CD} = \text{CE} - \text{DE} = r - h\,,$$

and
$$\cos \tfrac{1}{2}\text{C} = \frac{\text{CD}}{\text{AC}} = \frac{r-h}{r}\,,$$

whence C is found, and therefore s.

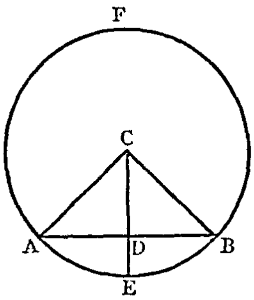


Fig. 14.

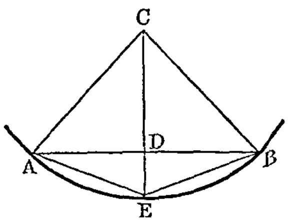


Fig. 15.

§ 32. *Huygens's Approximation to the Length of a Circular Arc.*—Let AB (fig. 15) $= p$ be the chord of the arc AEB, and AE $=$ EB $= q$ that of half the arc, then the arc AEB $= \frac{1}{3}(8q - p)$ approximately.

For, let r denote the radius, s the arc AEB, and 2θ the angle ACB, then $\theta = \dfrac{s}{2r}$. Again, AB $= p = 2\text{AD} = 2r \sin\theta = 2r \sin\dfrac{s}{2r}$; and similarly $q = 2r \sin\dfrac{s}{4r}$.

Now
$$\sin\theta = \theta - \frac{\theta^3}{\underline{|3}} + \frac{\theta^5}{\underline{|5}} - \&c.\,;$$

therefore
$$p = 2r\left\{\frac{s}{2r} - \frac{1}{\underline{|3}}\left(\frac{s}{2r}\right)^3 + \frac{1}{\underline{|5}}\left(\frac{s}{2r}\right)^5 - \&c.\right\}$$

$$= s - \frac{s^3}{2\,.\,3\,.\,4\,.\,r^2} + \frac{s^5}{2\,.\,3\,.\,4\,.\,5\,.\,16\,.\,r^4} - \&c.$$

Similarly
$$8q = 16r\left\{\frac{s}{4r} - \frac{1}{\underline{|3}}\left(\frac{s}{4r}\right)^3 + \frac{1}{\underline{|5}}\left(\frac{s}{4r}\right)^5 - \&c.\right\}$$

$$= 4s - \frac{s^3}{2\,.\,3\,.\,4\,.\,r^2} + \frac{s^5}{2\,.\,3\,.\,4\,.\,5\,.\,64\,.\,r^4} - \&c.$$

Hence, neglecting powers of $\dfrac{s}{r}$ beyond the fourth, we obtain

$$\frac{8q-p}{3} = s\left(1 - \frac{s^4}{7680r^4}\right) = s$$

approximately.

In practice it is sometimes more convenient to use the equivalent form

$$s = 2q + \tfrac{1}{3}(2q - p)\,.$$

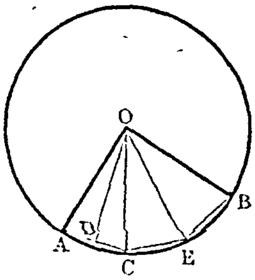


Fig. 16.

§ 33. *Area of Sector of a Circle.*—Let the sector be OAB (fig. 16). Divide the arc AB into n equal parts, and draw the chords of these. Let P denote the perimeter of the broken line AB, A the area of the polygon AOB, and p the altitude of any one of the n equal triangles of which this polygon is made up.

Now in the limit, when n is indefinitely increased, P becomes the arc AB $= s$, a result which we symbolize thus—

$$\mathop{\mathrm{L}}_{n=\infty} \mathrm{P} = \text{arc AB} = s\,.$$

Similarly
$$\mathop{\mathrm{L}}_{n=\infty} p = \text{radius} = r\,.$$

Again, the area of the sector is equal to the area of the polygon when the broken line AB becomes the arc AB, that is,

$$\text{sector} = \mathop{\mathrm{L}}_{n=\infty} \mathrm{A} = \mathop{\mathrm{L}}_{n=\infty} \tfrac{1}{2}p \times \mathrm{P} = \tfrac{1}{2} \mathop{\mathrm{L}}_{n=\infty} p \times \mathop{\mathrm{L}}_{n=\infty} \mathrm{P}\,.$$
$$= \tfrac{1}{2}rs\,.$$

§ 34. Let S denote the area of a sector of a circle, then, by means of the above result and § 27, we have

$$(\alpha) \quad \mathrm{S} = \tfrac{1}{2}sr\,,$$
$$(\beta) \quad \mathrm{S} = \tfrac{1}{2}r\theta\,.\,r = \tfrac{1}{2}r^2\theta\,.$$

§ 35. We proceed to find the area of a sector of a circle in the following additional cases:—

(α) *When the chord of the sector and the radius of the circle are given.*—In fig. 14 let AB $= 2c$, and let AC $= r$, then we have

$$\sin\frac{\text{ACB}}{2} = \frac{\text{AD}}{\text{AC}} = \frac{c}{r}\,;$$

whence ACB and therefore θ is known, and S can be found by § 34.

ACB has two values, the smaller one giving the area of the minor, and the larger that of the major conjugate sector.

(β) *When the chord and height of the chord are given.*—Let DE (fig. 14) $= h$ and AB $= 2c$, then

$$\text{AC}^2 = r^2 = \text{AD}^2 + \text{DC}^2 = c^2 + (r-h)^2, \text{ whence}$$

$r = \dfrac{c^2 + h^2}{2h}$, and therefore by previous case the area can be found.

(γ) *When the chord and angle subtended at the centre are given.*—Let AB (fig. 14) $= 2c$ and ACB $= \theta$, then

$$\frac{c}{r} = \sin\frac{\text{ACB}}{2}, \text{ or } r = \frac{c}{\sin\frac{1}{2}\theta}\,,$$

therefore area of sector $= \frac{1}{2}r^2\theta = \frac{1}{2}\left(\dfrac{c}{\sin\frac{1}{2}\theta}\right)^2 \times \theta\,.$

§ 36. *Area of a Circle.*—The circle being a sector whose arc is the whole circumference we obtain at once

$$\text{area of circle} = \tfrac{1}{2}r \times s = \tfrac{1}{2}r \times 2\pi r = \pi r^2.$$

An independent proof of this proposition might be given by means of the inscribed and circumscribed polygons, and from the area of a circle the area of a sector can be deduced. The infinitesimal calculus affords a simple and elegant proof (see § 44).

§ 37. If A denote the area, r the radius, $d = 2r$ the diameter, and C the circumference of a circle, we have

$$(\alpha) \quad \mathrm{A} = \pi r^2,$$
$$(\beta) \quad \mathrm{A} = \tfrac{1}{2} \times 2\pi r \times r = \tfrac{1}{2}\mathrm{C}r\,,$$
$$(\gamma) \quad \mathrm{A} = \frac{4\pi^2 r^2}{4\pi} = \frac{\mathrm{C}^2}{4\pi}\,,$$
$$(\delta) \quad \mathrm{A} = \frac{\pi 4r^2}{4} = \frac{\pi d^2}{4}\,.$$

Whence we see that the area of a circle is obtained by multiplying
(α) the square of its radius by $\pi = 3\cdot 14159$,
(β) the radius by half the circumference,
(γ) the square of the circumference by $\dfrac{1}{4\pi} = \cdot 07957$,
(δ) the square of the diameter by $\frac{1}{4}\pi = \cdot 78539$.

§ 38. Again, from the above formulæ we deduce

$$(\alpha) \quad r = \frac{1}{\sqrt{\pi}}\mathrm{A} = \cdot 5641896 \times \mathrm{A}\,,$$
$$(\beta) \quad d = \frac{2}{\sqrt{\pi}}\mathrm{A} = 1\cdot 1283792 \times \mathrm{A}\,,$$
$$(\gamma) \quad c = 2\sqrt{\pi}\mathrm{A} = 3\cdot 5449077 \times \mathrm{A}\,,$$

thus obtaining radius, diameter, and circumference from area.

§ 39. *Area of a Circular Ring.*—Let r and r_1 denote the radii of the outer and inner circles respectively (fig. 17), then the area of the space between them

$$= \pi r^2 - \pi r_1^2 = \pi(r + r_1)(r - r_1)\,.$$

The circles need not be concentric, and the reader should note that the area of the ring is equal to the area of an ellipse whose major and minor axes are $r + r_1$ and $r - r_1$ (see § 51).

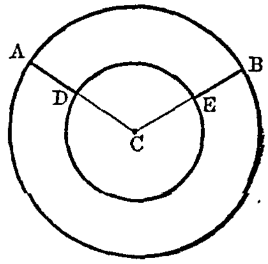


Fig. 17.

§ 40. *Area of the Sector of an Annulus.*—Let angle ACB $= \theta$ in fig. 17, then the area of ABED

$$= \text{sector ACB} - \text{sector DCE}$$
$$= \tfrac{1}{2}r^2\theta - \tfrac{1}{2}r_1^2\theta\,,$$
$$= \tfrac{1}{2}\theta(r + r_1)(r - r_1)\,.$$

Again, let $AB=l$, $DE=l_1$, and $CA-CD=r-r_1=h$, then

$$r=\frac{l}{\theta}\text{ and }r_1=\frac{l_1}{\theta}\text{ ; therefore}$$

$$r+r_1=\frac{1}{\theta}(l+l_1),\text{ and}$$

$$\text{area of sector}=\tfrac{1}{2}\theta(r+r_1)(r-r_1)=\tfrac{1}{2}\theta\left(\frac{l+l_1}{\theta}\right)h=\tfrac{1}{2}h(l+l_1).$$

§ 41. *Area of a Segment of a Circle.*—(a) *When the radius and the angle subtended at the centre are given.*—In fig. 14, let AEB be a segment of a circle, then its area

$$\begin{aligned}&=\text{sector ACB}-\text{triangle ACB.}\\&=\tfrac{1}{2}r^2\theta-\tfrac{1}{2}r^2\sin\theta\ (\S\S\ 9,\ 34)\\&=\tfrac{1}{2}r^2(\theta-\sin\theta).\end{aligned}$$

If the segment be greater than a semicircle $\sin\theta$ is negative and the formula becomes

$$\tfrac{1}{2}r^2(\theta+\sin\theta),$$

as is also geometrically evident.

We might in a similar manner find the area of a segment of a circle

(β) when the chord and radius are given,
(γ) when the chord and its height are given,
(δ) when the radius and height of the chord are given,
(ϵ) when the chord and angle subtended by the chord are given.

In all these cases the method of proceeding is obvious, a segment being the difference between a sector and a triangle.

§ 42. *Area of a Lune.*—Let ADB and ACB (fig. 18) be two segments of circles, then the area of the lune ADBC

$$=\text{segment ADB}-\text{segment ACB.}$$

Hence if we so choose our data that we can determine the areas of the two segments we have only to take their difference to find the area of the lune.

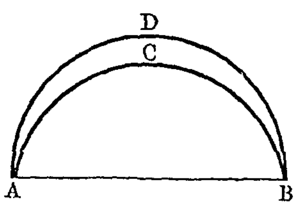


Fig. 18.

§ 43. *Area of a Circular Zone.*—Let AB and CD (fig. 19) be two parallel chords, then the area of the zone ABCD

$$\begin{aligned}&=\text{circle}-\text{segment AHB}-\text{segment DFC;}\\\text{or}\quad&=\text{segment AED}+\text{trapezium ABCD}+\text{segment BGC}\\&=2\text{ segment AED}+\text{trapezium ABCD.}\end{aligned}$$

§ 44. The INFINITESIMAL CALCULUS (*q.v.*) furnishes a simple and elegant proof of the formulæ for the areas of a circle and a sector. If $y=\phi(x)$ be the equation to a plane curve referred to rectangular

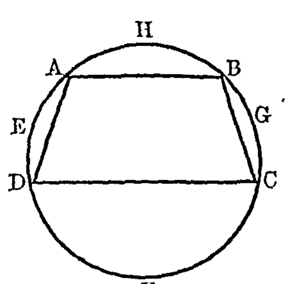


Fig. 19.

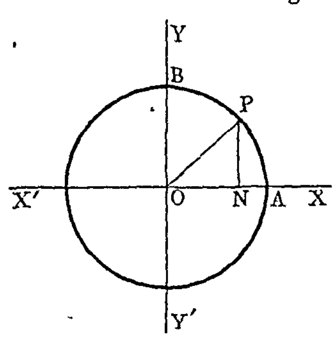


Fig. 20.

axes, then the area between the curve, the axis of x, and two ordinates corresponding to the abscissæ a and b is represented by the integral

$$\int_a^b\phi(x)dx.$$

Let x and y be the coordinates of P (fig. 20), then if $OP=r$ the equation to the circle is $y^2=r^2-x^2$, and therefore

$$\text{area of quadrant AOB}=\int_0^r\sqrt{r^2-x^2}\,dx$$

$$=\left[\frac{r^2}{2}\sin^{-1}\frac{x}{r}+\frac{x}{2}\sqrt{r^2-x^2}\right]_0^r=\frac{r^2}{2}\times\frac{\pi}{2}=\frac{\pi r^2}{4},$$

and therefore area of whole circle $=\pi r^2$.

§ 45. If the equation to a plane curve be given in polar coordinates, the area bounded by two radii and the curve is equal to

$$\tfrac{1}{2}\int_{\theta_1}^{\theta_2}r^2d\theta,$$

where θ_1 and θ_2 are the values of θ corresponding to the limiting radii.

For example, let AOP (fig. 20) be θ, then area of circle

$$=\frac{r^2}{2}\int_0^{2\pi}d\theta=\frac{2\pi r^2}{2}=\pi r^2\text{ as before.}$$

The area of a sector can be found in a similar manner.

B. *The Parabola.*

§ 46. *Length of an Arc of any Plane Curve.*—If a plane curve be referred to rectangular axes, then the length of any arc of the curve

$$=s=\int\left\{1+\left(\frac{dy}{dx}\right)^2\right\}^{\frac{1}{2}}dx=\int\left\{1+\left(\frac{dx}{dy}\right)^2\right\}^{\frac{1}{2}}dy$$

taken between proper limits, *i.e.*, the extremities of the arc. See INFINITESIMAL CALCULUS.

§ 47. *Arc of a Parabola.*—Let the axes of coordinates be the axis

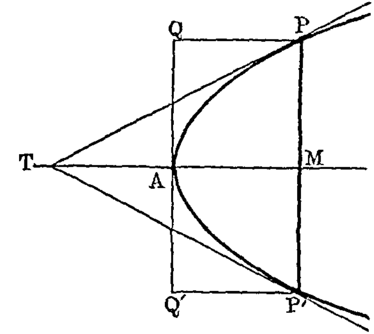


Fig. 21.

of x and the tangent at the vertex A (fig. 21), then, the equation to the parabola being $y^2=2mx$, where $m=2a=\frac{1}{2}$ latus rectum, we have

$$\frac{dx}{dy}=\frac{y}{m},\text{ and hence}$$

$$\begin{aligned}s=\text{arc AP}&=\int_0^{y_1}\left\{1+\frac{y^2}{m^2}\right\}^{\frac{1}{2}}dy\\&=\frac{y_1\sqrt{y_1^2+m^2}}{2m}+\frac{m}{2}\log_e\left(\frac{y_1+\sqrt{y_1^2+m^2}}{m}\right);\end{aligned}$$

therefore whole arc $PAP'=\frac{y_1}{m}\sqrt{y_1^2+m^2}+m\log_e\left(\frac{y_1+\sqrt{y_1^2+m^2}}{m}\right)$.

Since $y_1^2=2mx_1$, the formula may be written

$$\text{arc PAP}'=\sqrt{4x_1^2+y_1^2}+\frac{y_1^2}{2x_1}\log_e\left(\frac{2x_1+\sqrt{4x_1^2+y_1^2}}{y_1}\right).$$

§ 48. *Area of a Parabola.*—Taking the equation to the parabola in the form $y^2=4px$, we get

$$\text{area of segment PAP}'\text{ (fig. 21)}=2\int_0^{x_1}2\sqrt{px}\,dx$$

$$=\tfrac{8}{3}p^{\frac{1}{2}}x_1^{\frac{3}{2}}=\tfrac{4}{3}x_1y_1=\frac{y_1^3}{3p}.$$

From these formulæ we see that the area of a parabolic segment varies directly as the cube of the square root of the abscissa, and directly as the cube of the ordinate, and that it is equal to $\frac{2}{3}$ rectangle PQQ′P′, or $\frac{4}{3}$ triangle PTP′.

A similar relation holds for the segment cut off by any chord, and thus the area of any parabolic segment can be determined in terms of any data that are sufficient to determine the segment.

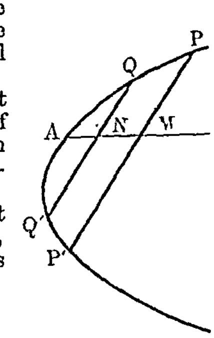


Fig. 22.

§ 49. *Area of a Parabolic Zone.*—Let PM (fig. 22) $=y_1$, $QN=y_2$, $AM=x_1$, $AN=x_2$, and let the ordinates be inclined to the axis at an angle α.

$$\begin{aligned}\text{Area of zone PQQ′P′}&=\text{segment PAP′}\\&\quad-\text{segment QAQ′}\\&=\frac{y_1^3-y_2^3}{3p}\times\sin\alpha.\end{aligned}$$

Now $y_1^2=4px_1$ and $y_2^2=4px_2$, therefore $\frac{y_1^2-y_2^2}{4(x_1-x_2)}=p$, and hence on substituting for p we have area of zone

$$=\tfrac{4}{3}(x_1-x_2)\left(\frac{y_1^3-y_2^3}{y_1^2-y_2^2}\right)\sin\alpha=\tfrac{4}{3}\,\frac{x_1-x_2}{y_1+y_2}(y_1^2+y_1y_2+y_2^2)\sin\alpha.$$

C. *The Ellipse.*

§ 50. *Circumference of an Ellipse.*—The equation to the ellipse being $\frac{x^2}{a^2}+\frac{y^2}{b^2}=1$, where a and b are the semiaxes, we have

$$\frac{dy}{dx} = -\frac{b^2x}{a^2y}, \text{ and therefore (fig. 23)}$$

arc of quadrant AB $= \int_0^a \left\{ \frac{a^2 - e^2x^2}{a^2-x^2} \right\}^{\frac{1}{2}} dx$, where $e^2 = \frac{a^2-b^2}{a^2}$.

This integral may be shown to be equal to the series

$$\frac{\pi a}{2}\left(1 - \frac{e^2}{2^2} - \frac{1\,.\,3e^4}{2^2\,.\,4^2} - \frac{1\,.\,3^2\,.\,5e^6}{2^2\,.\,4^2\,.\,6^2} - \&c. \right),$$

a rapidly converging series when e is a small fraction.

By taking more and more terms of the above series we can approximate as nearly as we please to the circumference of an ellipse. For example, we have quadrant AB

$$= \frac{\pi a}{2}\left(1 - \frac{e^2}{4} \right) = \frac{\pi a}{2}\left(1 - \frac{e^2}{2} \right)^{\frac{1}{2}}$$

to a first approximation; hence whole circumference

$$= \pi \left\{ \frac{(2a)^2 + (2b)^2}{2} \right\}^{\frac{1}{2}} \text{ nearly.}$$

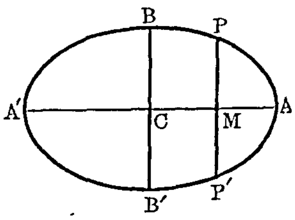


Fig. 23

§ 51. *Area of an Ellipse.*—We have at once

$$\text{area} = 4\int_0^a y dx 4 = \frac{b}{a}\int_0^a \sqrt{a^2 - x^2}dx.$$

But $\int_0^a \sqrt{a^2-x^2}dx$ is the area of the quadrant of a circle of radius a. Thus

$$\text{area of ellipse} = 4\frac{b}{a}\,\frac{\pi a^2}{4} \text{ (§ 44)}$$
$$= \pi ab.$$

The following proof is worth the reader's attention. By a well-known theorem in conic sections the orthogonal projection of a circle on a given plane is an ellipse. Now, if A denote the area of any plane figure, A′ the area of the projected figure, and θ the angle between the planes it can easily be shown, by dividing the two areas by planes indefinitely near to each other and perpendicular to the common section of the planes, that

$$A\cos\theta = A'.$$

In the case of the circle and ellipse $A = \pi a^2$ and $\cos\theta = \frac{b}{a}$;

hence area of ellipse $= \pi a^2 \times \frac{b}{a} = \pi ab$.

§ 52. *Area of an Ellipse in terms of a Pair of Conjugate Diameters.*—Let a' and b' denote the semiconjugate diameters, and α the angle between them, then by an elementary property of the ellipse

$$ab = a'b'\sin\alpha;$$

hence area of ellipse $= \pi a'b'\sin\alpha$.

D. *The Hyperbola.*

§ 53. *Area of a Segment of an Hyperbola.*—The equation of an hyperbola being $\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1$, we have

$$y = \frac{b}{a}\sqrt{x^2-a^2}\text{; hence (fig. 24)}$$

$$\text{area of the segment PAP}' = 2\,\frac{b}{a}\int_a^{x_1}\sqrt{x^2-a^2}dx$$

$$= \frac{b}{a}x_1\sqrt{x_1^2-a^2} - ab\log_e\left(\frac{x_1+\sqrt{x_1^2-a^2}}{a}\right)$$

$$= x_1y_1 - ab\log_e\left(\frac{x_1}{a}+\frac{y_1}{b}\right).$$

§ 54. *Area of a Sector of an Hyperbola.*—The sector PAP′C is equal to triangle PCP′ − segment PAP′

$$= x_1y_1 - \left\{ x_1y_1 - ab\log_e\left(\frac{x_1}{a}+\frac{y_1}{b}\right)\right\}$$

$$= ab\log_e\left(\frac{x_1}{a}+\frac{y_1}{b}\right).$$

§ 55. *Area of a Zone of an Hyperbola.*—In fig. 24 the zone PP′Q′Q

$$= \text{segment QAQ}' - \text{segment PAP}'$$

$$= x_2y_2 - ab\log_e\left(\frac{x_2}{a}+\frac{y_2}{b}\right) - x_1y_1 + ab\log_e\left(\frac{x_1}{a}+\frac{y_1}{b}\right)$$

$$= x_2y_2 - x_1y_1 - ab\log_e\left(\frac{ay_2+bx_2}{ay_1+bx_1}\right), \text{ where}$$

x_1, y_1 and x_2, y_2 are the coordinates of P and Q respectively.

If the axes of coordinates be inclined at an angle α, we multiply the above results by $\sin\alpha$ to obtain the correct areas.

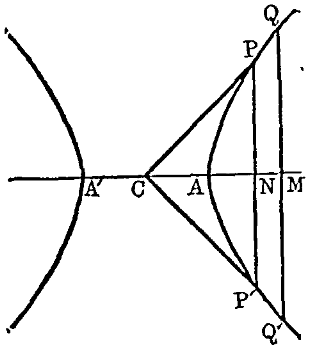


Fig. 24.

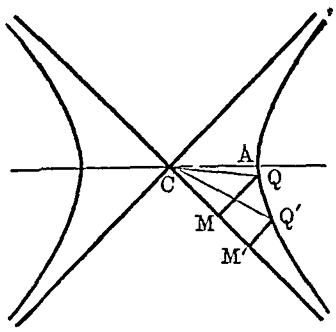


Fig. 25.

§ 56. *Area bounded by an Hyperbola and its Asymptotes.*—The equation of an hyperbola referred to its asymptotes is of the form

$$xy = c^2.$$

Let CM′ (fig. 25) $= x_1$, CM $= x_2$, Q′M′ $= y_1$, Q M $= y_2$, then, if α be the angle between the asymptotes,

$$\text{area of QMM}'\text{Q}' = \int_{x_2}^{x_1} y\sin\alpha\,dx$$

$$= c^2\sin\alpha\int_{x_2}^{x_1}\frac{dx}{x} = c^2\sin\alpha\log_e\left(\frac{x_1}{x_2}\right) = c^2\sin\alpha\log_e\left(\frac{y_2}{y_1}\right),$$

since $\qquad x_1 = \frac{c^2}{y_1}$ and $x_2 = \frac{c^2}{y_2}$.

Now $\qquad c^2 = \frac{a^2+b^2}{4}$ and $\sin\alpha = \frac{2ab}{a^2+b^2}$, and therefore

$$(\alpha) \qquad \text{area} = \tfrac{1}{2}ab\log_e\left(\frac{x_1}{x_2}\right) = \tfrac{1}{2}ab\log_e\left(\frac{y_2}{y_1}\right).$$

Again, let MM′ $= x_1 - x_2 = p$, then

$$c^2 = x_1y_1 = x_2y_2 = \frac{py_1y_2}{y_2-y_1}, \text{ therefore}$$

$$(\beta) \qquad \text{QMM}'\text{Q}' = \frac{py_1y_2}{y_2-y_1}\log_e\left(\frac{x_1}{x_2}\right)\sin\alpha = \frac{py_1y_2}{y_2-y_1}\log_e\left(\frac{y_2}{y_1}\right)\sin\alpha.$$

Again, since

$$\tfrac{1}{2}x_1y_1\sin\alpha = \tfrac{1}{2}c^2\sin\alpha = \tfrac{1}{2}x_2y_2\sin\alpha,$$

we have $\qquad$ triangle QCM = Q′CM′, and hence

the sector QCQ′ = QMM′Q′.

The corresponding results for a rectangular hyperbola are obtained by substituting in the above formulæ $\frac{1}{2}a^2$ for c^2 and 1 for $\sin\alpha$.

Section III.—Plane Irregular, Rectilineal, and Curvilineal Figures.

A. *Irregular Rectilineal Figures.*

§ 57. The area of any irregular polygon can be found by dividing it into triangles, trapeziums, &c., in the most convenient manner, and adding together all the areas. For example,

ABCDEF (fig. 26) = CKB + BKHA + AHF + FGE + EGID + DIC.

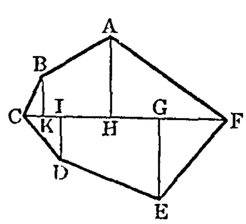


Fig. 26.

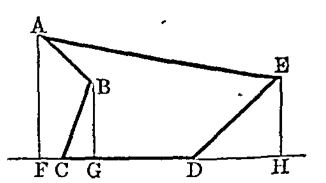


Fig. 27.

It may sometimes happen that some of the component figures have to be subtracted instead of added; for example,

ABCDE (fig. 27) = AFHE + BCG − AFGB − EDH.

§ 58. Again, the irregular rectilineal figure P_1P_2 . . . P_8P_9 (fig. 28) can be broken up into a series of triangles and trapeziums as shown in the figure, and hence its area can be found.

§ 59. A figure made up of straight lines may be measured by cutting it up into triangles by lines drawn from some one vertex to the others. For example (fig. 29),

ABCDEF = ABC + ACD + ADE + AEF.

If the polygon be concave some of the triangles will have to be subtracted.

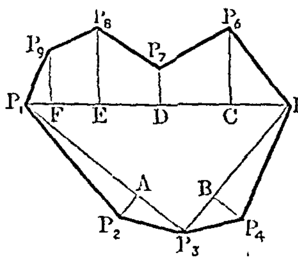


Fig. 28.

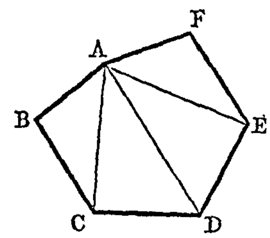


Fig. 29.

§ 60. *Area of a Polygon in terms of the Coordinates of its Angular Points.*—Let the coordinates of P, Q, R (fig. 30) be (x_1, y_1), (x_2, y_2), and (x_3, y_3) respectively, and let the axes be inclined at an angle α. Draw PL, QM, and RN parallel to OY, then

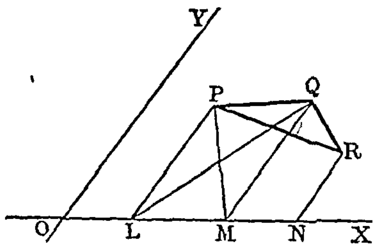


Fig. 30.

$$LM = OM - OL = x_2 - x_1,$$
$$MN = ON - OM = x_3 - x_2,$$
and
$$NL = ON - OL = x_3 - x_1.$$

Now $\quad PQR = PLMQ + QMNR - PLNR.$

But $\quad PLMQ = PLM + QMP = PLM + QLM$
$$= \tfrac{1}{2}PL \cdot LM \sin\alpha + \tfrac{1}{2}QM \cdot LM \sin(180° - \alpha) \ (\S\ 9,\ \beta)$$
$$= \tfrac{1}{2}(x_2 - x_1)(y_1 + y_2)\sin\alpha.$$

Similarly $\quad QMNR = \tfrac{1}{2}(x_3 - x_2)(y_2 + y_3)\sin\alpha,$

and $\quad PLNR = \tfrac{1}{2}(x_3 - x_1)(y_3 + y_1)\sin\alpha$; hence

$$\text{area of } PQR = \tfrac{1}{2}\sin\alpha\{y_1(x_2 - x_3) + y_2(x_3 - x_1) + y_3(x_1 - x_2)\};$$

or in the notation of determinants

$$= \tfrac{1}{2}\sin\alpha \begin{vmatrix} 1 & 1 & 1 \\ x_1 & x_2 & x_3 \\ y_1 & y_2 & y_3 \end{vmatrix}.$$

When the axes are rectangular $\sin\alpha = \sin 90° = 1$, and the formula for the area becomes

$$\tfrac{1}{2}\{y_1(x_2 - x_3) + y_2(x_3 - x_1) + y_3(x_1 - x_2)\}$$
$$= \tfrac{1}{2}\begin{vmatrix} 1 & 1 & 1 \\ x_1 & x_2 & x_3 \\ y_1 & y_2 & y_3 \end{vmatrix}.$$

§ 61. The area of any rectilineal figure of n sides can be found by taking any point within the figure and joining it to the n vertices of the figure, thus dividing it into n triangles the area of each of which can be obtained as in the preceding case.

We may, however, find the area of the figure directly.

For example, in fig. 31

$$PQRST = PP'T'T + TT'S'S + SS'R'R - RR'Q'Q - QQ'P'P,$$

and in fig. 32

$$PQRSTU = PP'U'U + RR'Q'Q + TT'S'S - PP'Q'Q - RR'S'S - TT'U'U.$$

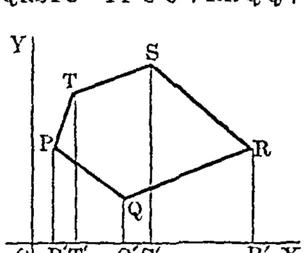


Fig. 31.

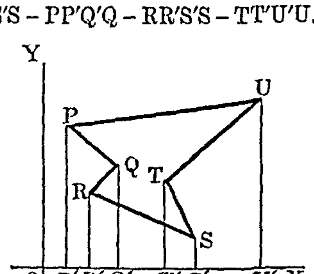


Fig. 32.

B. *Irregular Curvilineal Figures.*

§ 62. *Length of any Curve.*—If we divide the given arc into an even number of intervals and regard these as approximately circular, we can find an approximation to the length of the arc by means of Huygens's formula, § 32. For example, if we divide ABC (fig. 33) into four parts in D, B, and E, and draw the chords AD, AB, DB, BE, BC, and EC, then

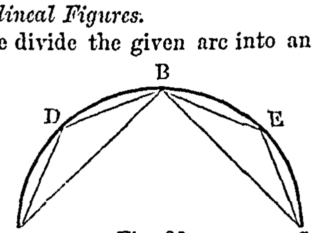


Fig. 33.

$$\text{arc } AC = AD + DB + BE + EC + \tfrac{1}{3}(AD + DB + BE + EC - AB - BC)$$

approximately.

For other methods of approximation, see Rankine's *Rules and Tables.*

§ 63. *Area of an Irregular Curvilineal Figure.*—For rough approximations the following, called the trapezoidal method, may be used:—

Divide A_1A_n (fig. 34) into n equal parts, and through the points

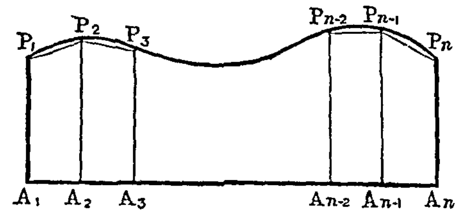


Fig. 34.

of division draw the ordinates, called by surveyors offsets, A_1P_1, A_2P_2, &c.

Let $\quad A_1P_1 = s_1,\ A_2P_2 = s_2$, &c., $A_nP_n = s_n$, and
$\quad A_1A_2 = A_2A_3 = \ .\ .\ .\ = A_{n-1}A_n = a.$

Join P_1P_2, P_2P_3, &c., then the area of the polygon $A_1A_nP_nP_2P_1$
$$= A_1A_2P_2P_1 + A_2A_3P_3P_2 + \ .\ .\ .\ .\ + A_{n-1}A_nP_nP_{n-1}$$
$$= \tfrac{1}{2}a(s_1 + s_2) + \tfrac{1}{2}a(s_2 + s_3) + \ .\ .\ .\ .\ + \tfrac{1}{2}a(s_{n-1} + s_n)\ (\S\ 13,\ a)$$
$$= a\{\tfrac{1}{2}(s_1 + s_n) + s_2 + s_3 + \ .\ .\ .\ . + s_{n-1}\}.$$

If we take n sufficiently great the difference between the area of the polygon and the curvilineal figure can be made as small as we please, in other words, the smaller we make a the more accurately will the above formula represent the area of the curvilineal figure.

The curve may either be wholly convex or wholly concave to the line A_1A_n, or partly convex and partly concave.

§ 64. *Simpson's Rule.*—Let A_1A_n (fig. 34) be divided into an *even* number of equal parts, and as before through the points of division draw the ordinates A_1P_1, A_2P_2, &c.

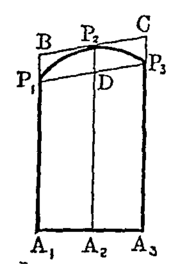


Fig. 35.

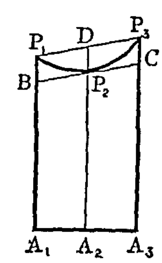


Fig. 36.

Let $A_1A_3P_3P_1$ (figs. 35, 36) be a part of the figure thus divided; join P_1P_3, and through P_2 draw BC parallel to P_1P_3 to meet A_1P_1 in B and A_3P_3 in C. Conceive a parabola to be drawn through $P_1P_2P_3$ having its axis parallel to the ordinates, then

$$A_1P_1P_2P_3A_3 = \text{trapezium } A_1P_1DP_3A_3 \pm \text{parabolic segment } P_1P_2P_3$$
$$= a(s_1 + s_3) \pm \tfrac{4}{3}a\{s_2 \sim \tfrac{1}{2}(s_1 + s_3)\} = \tfrac{1}{3}a(s_1 + 4s_2 + s_3).$$

Now when the points P_1, P_2, P_3 are near each other the parabolic curve will coincide very nearly with the given curve; hence

$$A_1P_1P_2P_3A_3 = \tfrac{1}{3}a(s_1 + 4s_2 + s_3) \text{ very nearly.}$$

Similarly $\quad A_3P_3P_5A_5 = \tfrac{1}{3}a(s_3 + 4s_4 + s_5)$, &c.;

hence whole area of figure

$$= \tfrac{1}{3}a\{s_1 + s_n + 2(s_3 + s_5 + \ .\ .\ .\ . + s_{n-2}) + 4(s_2 + s_4 + \ .\ .\ .\ . + s_{n-1})\};$$

whence the rule:—add together the two extreme ordinates, twice the sum of the intermediate odd ordinates, and four times the sum of the even ones, and multiply this result by one-third of the common distance between the ordinates; the result is the area,—*accurately* if the curved boundary be the arc of a parabola, in other cases approximately.

The curve may either be wholly convex or wholly concave to the line A_1A_n, or partly convex and partly concave, provided in the latter case the points of contrary flexure occur only at the odd ordinates, for otherwise the intermediate arcs could not be even approximately parabolic. When points of contrary flexure occur ordinates may be drawn at these points, and the intermediate arcs being found separately may be added to obtain the whole area.

§ 65. In the two preceding sections we investigated two formulæ for approximating to the areas of curvilinear figures. We now proceed to consider the subject more generally.

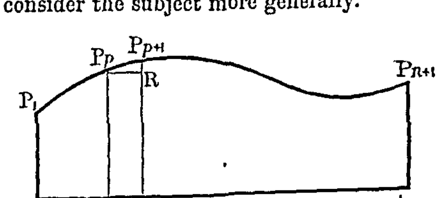


Fig. 37.

Let the equation to the curve $P_1P_pP_{n+1}$ (fig. 37) agree with the

equation $y = \mathrm{A} + \mathrm{B}x + \mathrm{C}x^2 + \ldots + \mathrm{K}x^n$ for $n+1$ points between P_1 and P_{n+1}, then the area of the curvilinear figure bounded by the straight lines $\mathrm{A}_1\mathrm{P}_1$, $\mathrm{A}_1\mathrm{A}_{n+1}$, and $\mathrm{A}_{n+1}\mathrm{P}_{n+1}$ and the curve $\mathrm{P}_1\mathrm{P}_{n+1}$ will agree very nearly with the curvilinear figure bounded by the same straight lines and the curve whose equation is $y = \mathrm{A} + \mathrm{B}x + \mathrm{C}x^2 + \ldots + \mathrm{K}x^n$, and the greater the number of common points the closer will be the agreement.

Let $\mathrm{A}_1\mathrm{A}_{n+1}$ be divided into n equal parts, each equal to h, then $\mathrm{A}_1\mathrm{A}_{n+1} = nh$. Now

when $x=0$, $y = y_1 = \mathrm{A}$;

when $x=h$, $y = y_2 = \mathrm{A} + \mathrm{B}h + \mathrm{C}h^2 + \ldots + \mathrm{K}h^n$;

when $x=2h$, $y = y_3 = \mathrm{A} + \mathrm{B}(2h) + \mathrm{C}(2h)^2 + \ldots + \mathrm{K}(2h)^n$;

. . . .

when $x=ph$, $y = y_{p+1} = \mathrm{A} + \mathrm{B}(ph) + \mathrm{C}(ph)^2 + \ldots + \mathrm{K}(ph)^n$;

. . . .

when $x=nh$, $y = y_{n+1} = \mathrm{A} + \mathrm{B}(nh) + \mathrm{C}(nh)^2 + \ldots + \mathrm{K}(nh)^n$.

From these $n+1$ equations the $n+1$ quantities A, B, ... K can be determined as functions of $y_1, y_2, \ldots\ldots y_{n+1}$, and h.

Next let $\mathrm{A}_1\mathrm{A}_{n+1}$ be divided into m equal parts each equal to h. Thus $mh = nh$ and hence $h = \frac{nh}{m}$

Now the area of the rectangle $\mathrm{A}_p\mathrm{A}_{p+1}\mathrm{P}_p\mathrm{R} = \mathrm{A}_p\mathrm{A}_{p+1} \times \mathrm{A}_p\mathrm{P}_p$.

But $\mathrm{A}_p\mathrm{P}_p = y_p = \mathrm{A} + \mathrm{B}(ph) + \mathrm{C}(ph)^2 + \ldots + \mathrm{K}(ph)^n$

$$= \mathrm{A} + \mathrm{B}\frac{p.nh}{m} + \mathrm{C}\left(\frac{p.nh}{m}\right)^2 + \ldots + \mathrm{K}\left(\frac{p.nh}{m}\right)^n,$$

since $$h = \frac{nh}{m};$$

and $$\mathrm{A}_p\mathrm{A}_{p+1} = h = \frac{nh}{m};$$

therefore area of $\mathrm{A}_p\mathrm{R}$

$$nh\left\{\frac{\mathrm{A}}{m} + \mathrm{B}nh\frac{p}{m^2} + \mathrm{C}n^2h^2\frac{p^2}{m^3} + \ldots + \mathrm{K}n^nh^n\frac{p^n}{m^{n+1}}\right\}.$$

Hence the area of the whole figure

$$= \mathrm{L}_{m=\infty}\sum_{p=1}^{p=m} nh\left\{\frac{\mathrm{A}}{m} + \mathrm{B}nh\frac{p}{m^2} + \mathrm{C}n^2h^2\frac{p^2}{m^3} + \ldots + \mathrm{K}n^nh^n\frac{p^n}{m^{n+1}}\right\}$$

$$= \mathrm{L}_{m=\infty} nh\left\{\mathrm{A}\frac{\mathrm{S}_0}{m} + \mathrm{B}nh\frac{\mathrm{S}_1}{m^2} + \mathrm{C}n^2h^2\frac{\mathrm{S}_2}{m^3} + \ldots + \mathrm{K}n^nh^n\frac{\mathrm{S}_n}{m^{n+1}}\right\},$$

where $$\mathrm{S}_n = 1^n + 2^n + 3^n + \ldots + m^n.$$

Now if we take the limit of each of the terms

$$\frac{\mathrm{S}_0}{m}, \frac{\mathrm{S}_1}{m^2}, \frac{\mathrm{S}_2}{m^3}, \ldots \frac{\mathrm{S}_n}{m^{n+1}},$$

we obtain area of curvilinear figure

$$= nh\left\{\mathrm{A} + \frac{\mathrm{B}}{2}nh + \frac{\mathrm{C}}{3}n^2h^2 + \ldots + \frac{\mathrm{K}}{n+1}n^nh^n\right\}.$$

From this general result we can deduce "Simpson's Rule" and also another rule called "Weddle's Rule."

Thus let $n=2$; that is, assume that the curve under consideration has three points in common with the curve whose equation is $y = \mathrm{A} + \mathrm{B}x + \mathrm{C}x^2$, *i.e.*, with a parabola, then

$$y_1 = \mathrm{A},$$
$$y_2 = \mathrm{A} + \mathrm{B}h + \mathrm{C}h^2,$$
$$y_3 = \mathrm{A} + 2\mathrm{B}h + 4\mathrm{C}h^2.$$

Now the area is approximately

$$= 2h\{\mathrm{A} + \tfrac{1}{2}\mathrm{B}2h + \tfrac{1}{3}\mathrm{C}\,2^2h^2\}$$
$$= \tfrac{1}{3}h\{6\mathrm{A} + 6\mathrm{B}h + 8\mathrm{C}h^2\}$$
$$= \tfrac{1}{3}h\{y_1 + 4y_2 + y_3\}, \text{ Simpson's Rule.}$$

If we now put $n=6$, we have area of curvilinear figure

$$= 6h\{\mathrm{A} + \tfrac{1}{2}\mathrm{B}6h + \tfrac{1}{3}\mathrm{C}6^2h^2 + \tfrac{1}{4}\mathrm{D}6^3h^3 + \tfrac{1}{5}\mathrm{E}6^4h^4 + \tfrac{1}{6}\mathrm{F}6^5h^5 + \tfrac{1}{7}\mathrm{G}6^6h^6\}.$$

Now $$y_1 = \mathrm{A},$$
$$y_2 = \mathrm{A} + \mathrm{B}h + \mathrm{C}h^2 + \ldots + \mathrm{G}h^6,$$
. . . .
$$y_7 = \mathrm{A} + \mathrm{B}(6h) + \mathrm{C}(6h)^2 + \ldots\ \mathrm{G}(6h)^6.$$

From this system of equations we can determine A, B, C, . . . G, and substituting the values so obtained in the above expression we obtain the following remarkable formula for the approximate area:

$$\text{area} = \tfrac{3}{10}h\{(y_1 + y_3 + y_5 + y_7) + y_4 + 5(y_2 + y_4 + y_6)\}.$$

This formula, called Weddle's Rule, gives the closest approximation to the curvilinear area that can be obtained by any simple rule.

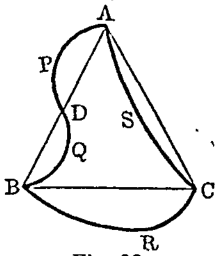


Fig. 38.

We are now in a position to find the approximate area of any irregular plane figure. For the given figure can be divided into plane rectilinear and curvilinear figures, the areas of which can be separately determined by the rules already given. For example, APQRS (fig. 38)

$$= \mathrm{ABC} + \mathrm{APD} + \mathrm{BRC} - \mathrm{DQB} - \mathrm{ASC}.$$

PART II. SOLIDS.

Section I. Solids contained by Planes.

A. *Prisms, Pyramids, and Prismatoids.*

§ 66. *Volume of a Right Prism.*—First let the prism be a rectangular parallelepiped (fig. 39), and let the side AB contain a units of length, BC b units of length, and CD c units of length. If we divide AB into a equal parts, BC into b equal parts, and CD into c equal parts, and if, through the points of division we draw planes parallel to the sides of the parallelepiped, these planes will divide it into a series of parallelepipeds, whose edges are each equal to the unit of length. Each horizontal layer contains ab of these cubes, and since there are c layers the whole number of cubes will be abc. But each of these is the unit of volume, and therefore

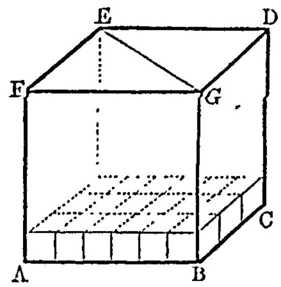


Fig. 39.

volume of ABCD $= abc = ab \times c =$ area of base ABC $\times$ altitude c.

In the above demonstration we have assumed the edges to be commensurable, but from § 2 it follows that the proof will hold also when the edges are incommensurable. If the parallelepiped be cut by a plane BGE it will be divided into two equal triangular right prisms, and hence

volume of right triangular prism $= \tfrac{1}{2}ab \times c =$ area of its base $\times$ altitude.

Since every prism can be divided into triangular prisms as in fig. 40, we have at once

volume of right prism A′ABCDE $=$ A′ABC $+$ A′ACD $+$ A′ADE
$= \mathrm{ABC} \times \mathrm{BB'} + \mathrm{ACD} \times \mathrm{CC'} + \mathrm{ADE} \times \mathrm{DD'}$
$= (\mathrm{ABC} + \mathrm{ACD} + \mathrm{ADE}) \times$ altitude
(since $\mathrm{BB'} = \mathrm{CC'} = \mathrm{DD'} =$ altitude)
$=$ area of base ABCDE $\times$ altitude.

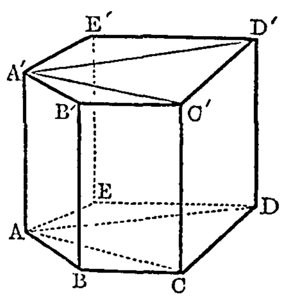


Fig. 40.

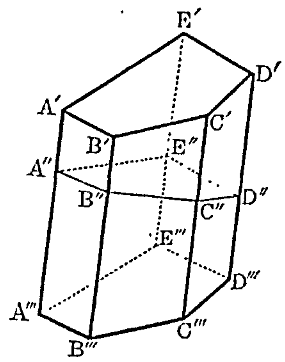


Fig. 41.

§ 67. *Volume of an Oblique Prism.*—Draw the right section A″B″C″D″E″ (fig. 41), and let A′ denote its area and A the area of the base A′B′C′D′E′. Let l denote the length of the prism, h its altitude, and α the angle between the planes A′B′C′D′E′ and A″B″C″D″E″.

Conceive the part above the right section placed at the other extremity of the prism. Then we have a right prism, whose volume $= \mathrm{A'} \times l$ (§ 66); but $\mathrm{A'} = \mathrm{A}\cos\alpha$, since A′ is the projection of A (§ 51),

and $$l = \frac{h}{\cos\alpha}; \text{ hence}$$

$$\text{volume} = \mathrm{A'} \times l = \mathrm{A}\cos\alpha \times \frac{h}{\cos\alpha} = \mathrm{A} \times h;$$

or the volume of any prism is equal to the area of its base multiplied by its altitude.

§ 68. *Surface of a Prism.*—Since the lines $A''B''$, $B''C''$, &c. (fig. 41), which make up the perimeter of the right section are all in one plane perpendicular to the parallel edges $A'A'''$, $B'B'''$, &c., they are perpendicular to these edges and are therefore the altitudes of the parallelograms $A'B'B'''A'''$, $B'C'C'''B'''$, &c., respectively. The lateral surface of the prism is equal to the sum of these parallelograms, and therefore

$$=A'A'''\times A''B''+B'B'''\times B''C''+\ \ldots\ldots$$
$$=A'A'''(A''B''+B''C''+\ \ldots\ldots),$$

since $\quad A'A'''=B'B'''=\text{\&c.};$

or the lateral surface of any prism is equal to the perimeter of its right section multiplied by the length of the prism.

If the prism be *right*, that is, if the faces be perpendicular to the base, then its lateral surface is equal to the perimeter of its base multiplied by its length.

The whole surface of any prism is obtained by adding to the lateral surface the areas of its bases.

§ 69. If the prism be *regular*, that is, if the bases be regular polygons, then

area of base $=a^2\times\frac{n}{4}\cot\frac{180°}{n}$ (§ 18, γ), where n is the number of sides each of length a, and therefore

$$\text{volume}=a^2\times\frac{n}{4}\cot\frac{180°}{n}\times h,$$

where h is the altitude of the prism.

Again, if the prism be right and regular, then

$$\text{its lateral surface}=nah+2a^2\times\frac{n}{4}\cot\frac{180°}{n}.$$

§ 70. *Volume of a Pyramid.*—Let VABC (fig. 42) be for simplicity a triangular pyramid. Divide VA into n equal portions, and through the points of section draw planes parallel to the base ABC, and through BC and through the intersections of these planes with VBC draw planes parallel to VA. Let h denote the altitude of the pyramid, then the distance of the base of the r^{th} prism from the vertex V

$$=r\times\frac{h}{n},$$

and, if A denote the area of ABC, we have

$$\frac{\text{base of } r^{\text{th}} \text{ prism}}{\text{A}}=\frac{r^2h^2}{n^2}\times\frac{1}{h^2}=\frac{r^2}{n^2},$$

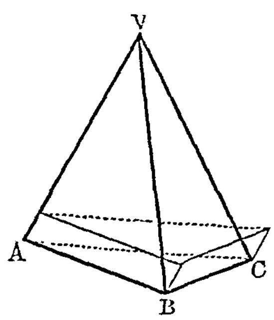


Fig. 42.

since, by a well-known theorem in solid geometry, the areas of sections of a pyramid made by planes parallel to the base are proportional to the squares of their altitudes.

Thus we have

$$\text{base of } r^{\text{th}} \text{ prism}=\frac{r^2}{n^2}\text{A, and therefore}$$

$$\text{its volume}=\frac{r^2}{n^2}\text{A}\times\frac{h}{n}\ (\S\ 67)$$
$$=\frac{h\text{A}}{n^3}\times r^2.$$

Therefore volume of whole pyramid

$$=h\text{A}\mathop{\mathrm{L}}_{n=\infty}\frac{1^2+2^2+\ \ldots\ +r^2+\ \ldots\ +n^2}{n^3}$$
$$=h\text{A}\mathop{\mathrm{L}}_{n=\infty}\frac{n(n+1)(2n+1)}{6n^3}=h\text{A}\times\tfrac{1}{3};$$

or the volume of any pyramid is equal to one-third of the area of its base multiplied by its height.

From this we see that pyramids on equal bases are to one another as their altitudes.

If the pyramid be *regular*, that is, if its base be a regular polygon the perpendicular through whose centre passes through the vertex,

$$\text{its volume}=\tfrac{1}{3}\times a^2\times\frac{n}{4}\cot\frac{180°}{n}\times h.$$

§ 71. *Surface of a Regular Pyramid.*—The lateral surface of the regular pyramid VABCDEF (fig. 43) is equal to the sum of the areas of the n congruent triangles which make up the lateral surface of the pyramid.

Now area of triangle $\text{VAB}=\frac{1}{2}\text{AB}\times\text{VG}$; hence whole lateral surface $=\frac{1}{2}n\text{AB}\cdot\text{VG}=\frac{1}{2}nal$, where l is the slant height and a the length of the side of the base.

Again, if $\text{VO}=h=$ altitude of pyramid, we have

$$l=\text{VG}=\sqrt{\text{VO}^2+\text{OG}^2}=\sqrt{h^2+\frac{a^2}{4}\cot^2\frac{180°}{n}},$$

therefore whole surface = base + lateral surface

$$=a^2\times\frac{n}{4}\cot\frac{180°}{n}+\tfrac{1}{2}na\sqrt{h^2+\frac{a^2}{4}\cot^2\frac{180°}{n}}$$
$$=\frac{na}{2}\left(\frac{a}{2}\cot\frac{180°}{n}+\sqrt{h^2+\frac{a^2}{4}\cot^2\frac{180°}{n}}\right).$$

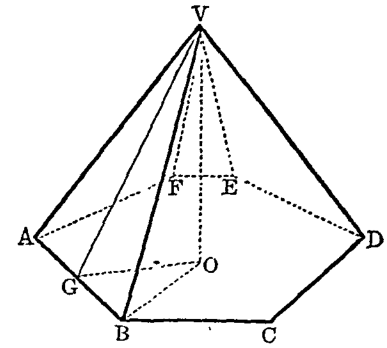


Fig. 43.

§ 72. *The Prismatoid.*—If we have a polyhedron whose bases are two polygons in parallel planes, the number of sides in each being the same or different, and if we so join the vertices of these bases that each line in order forms a triangle with the preceding line and one side of either base, the figure so formed is called a "prismatoid," and holds in stereometry a position similar to that of the trapezium in planimetry. To make the investigation of the volume of the prismatoid as simple as possible, we take the case where the lower base is a polygon of four and the upper one of three sides.

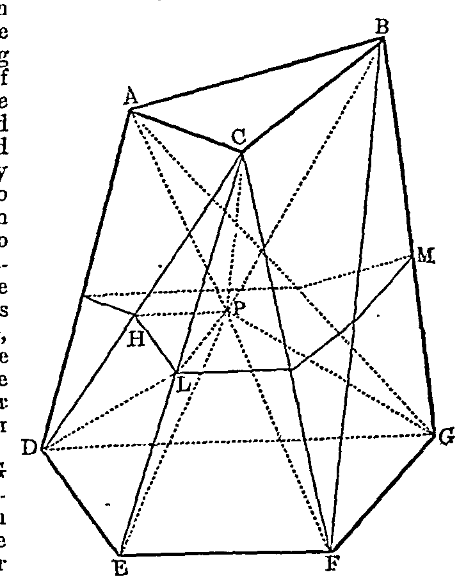


Fig. 44.

Let ABCDEFG (fig. 44) be the prismatoid, of which ABC or A_1 is the upper and DEFG or A_3 the lower base, and let HLM be the section equidistant from the bases. Take any point P in this section and join it to the corners of the prismatoid. We thus divide the polyhedron into two pyramids PABC and PDEFG, and a series of polyhedra of which CPDE may be taken as a specimen.

Let h be the altitude of the prismatoid, then $\frac{1}{2}h$ is the altitude of each of the pyramids PABC, PDEFG, and hence

$$\text{volume of PABC }=\tfrac{1}{6}h\text{A}_1,\text{ and}$$
$$\text{volume of PDEFG}=\tfrac{1}{6}h\text{A}_3.$$

Again join PH, PL, and LD, then

volume of CPDE = 2 volume of CPDL,
since DE = 2HL,
and volume of CPDL = 2 volume of CPHL,
hence volume of CPDE = 4 volume of CPHL.

Now volume of $\text{CPHL}=\frac{1}{6}h\times$ area of HLP, and therefore volume of $\text{CPDE}=\frac{4}{6}h\times$ area of HLP.

Similarly the volume of every such polyhedron is $\frac{4}{6}h\times$ the area of its own portion of the middle section. Hence if A_2 denote the area of the middle section we have

$$\text{volume of prismatoid}=\tfrac{1}{6}h\text{A}_1+\tfrac{1}{6}h\text{A}_3+\tfrac{4}{6}h\text{A}_2$$
$$=\tfrac{1}{6}h(\text{A}_1+4\text{A}_2+\text{A}_3).$$

§ 73. *Volume of the Frustum of a Pyramid.*—Let $A'A'''B'B'''C'C'''$ (fig. 45) be a frustum of the pyramid $VA'B'C'$, and let A_1 and A_3 denote the areas of the ends $A'B'C'$, $A'''B'''C'''$ respectively. Let $\text{VP}=x=$ altitude of pyramid $VA'''B'''C'''$, and let $\text{PQ}=h=$ altitude of frustum.

Now $\quad\left(\dfrac{x}{x+h}\right)^2=\dfrac{\text{A}_3}{\text{A}_1},\ \text{ whence } x=\dfrac{h\sqrt{\text{A}_3}}{\sqrt{\text{A}_1}-\sqrt{\text{A}_3}}.$

Again frustum $=\text{VA}'\text{B}'\text{C}'-\text{VA}'''\text{B}'''\text{C}'''$

$$=\tfrac{1}{3}\left\{\text{A}_1(x+h)-\text{A}_3x\right\}$$

$$=\tfrac{1}{3}\left\{\text{A}_1\left(\frac{h\sqrt{\text{A}_1}}{\sqrt{\text{A}_1}-\sqrt{\text{A}_3}}\right)-\text{A}_3\left(\frac{h\sqrt{\text{A}_3}}{\sqrt{\text{A}_1}-\sqrt{\text{A}_3}}\right)\right\}$$

$$=\tfrac{1}{3}h(\text{A}_1+\sqrt{\text{A}_1\text{A}_3}+\text{A}_3)\,;$$

a formula which applies to the frusta of all pyramids regular and irregular.

The above result may be otherwise expressed. For, let $\text{A}'\text{B}'=a_1$ and $\text{A}'''\text{B}'''=a_3$, then, if $\text{A}''\text{B}''\text{C}''$ be a section equidistant from the ends of the frustum, $\text{A}''\text{B}''=a_2=\tfrac{1}{2}(a_1+a_3)$.

Now $\text{A}_1=pa_1^2$ and $\text{A}_3=pa_3^2$ (see § 70);
hence $\text{A}_2=$area of $\text{A}''\text{B}''\text{C}''=pa_2^2=p\left(\frac{a_1+a_3}{2}\right)^2$, which gives

$$4\text{A}_2=pa_1^2+2pa_1a_3+pa_3^2=\text{A}_1+2\sqrt{\text{A}_1\text{A}_3}+\text{A}_3\,;$$

therefore volume of frustum

$$=\tfrac{1}{6}h(2\text{A}_1+2\sqrt{\text{A}_1\text{A}_3}+2\text{A}_3)=\tfrac{1}{6}h(\text{A}_1+4\text{A}_2+\text{A}_3)\,;$$

or the volume of the frustum of a pyramid is obtained by adding the areas of the ends to four times the area of the middle section, and multiplying the sum by one-sixth of the altitude.

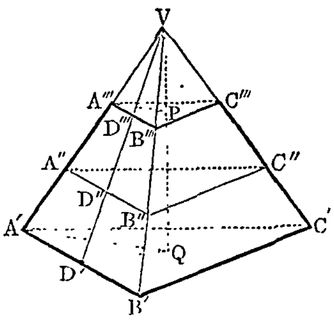


Fig. 45.

The above result can be obtained at once from § 72, since $\text{A}'\text{B}'\text{C}'\text{A}'''\text{B}'''\text{C}'''$ is a prismatoid with similar bases.

§ 74. *Surface of the Frustum of a Regular Pyramid.*—In fig. 45 let the perimeter of $\text{A}_1=p_1$, that of $\text{A}_2=p_2$, and that of $\text{A}_3=p_3$, and let $\text{VD}'=l_1$, $\text{VD}'''=l_3$, and therefore $\text{D}'\text{D}'''=\text{VD}'-\text{VD}'''=l_1-l_3=l$. The lateral surface of the frustum is equal to the difference between the lateral surfaces of the pyramids $\text{VA}'\text{B}'\text{C}'$ and $\text{VA}'''\text{B}'''\text{C}'''$,

$$=\tfrac{1}{2}p_1l_1-\tfrac{1}{2}p_3l_3\,.$$

But, since $\frac{l_1}{l_3}=\frac{a_1}{a_3}=\frac{na_1}{na_3}=\frac{p_1}{p_3}$, we have $l_1=\frac{p_1l}{p_1-p_3}$ and $l_3=\frac{p_3l}{p_1-p_3}$, therefore lateral surface of frustum

$$=\tfrac{1}{2}l\left(\frac{p_1^2-p_3^2}{p_1-p_3}\right)=l\left(\frac{p_1+p_3}{2}\right)=lp_2\,;$$

or the lateral surface of the frustum of a regular pyramid is equal to the product of the slant height and the perimeter of the section equidistant from the ends.

Otherwise.—The top and base being regular polygons, the inclined faces are congruent trapeziums. Let l be the height of each trapezium, and let there be n of them, then

$$\text{area of each face}=\frac{l}{2}\left(\frac{p_1}{n}+\frac{p_3}{n}\right),$$

and therefore the area of lateral surface $=\frac{l}{2}(p_1+p_3)=lp_2$.

§ 75. If h the altitude of the frustum be given, we deduce the slant height and then proceed as before. Thus let $\text{VP}=h_3$, $\text{VQ}=h_1$, and using the same notation as in §§ 72, 73, and 74 we have

$$\frac{h_1}{h_1-h_3}=\frac{a_1}{a_1-a_3}\,,\text{ which gives }h_1=\frac{a_1(h_1-h_3)}{a_1-a_3}=\frac{a_1h}{a_1-a_3}\,.$$

Again $\quad l_1^2=h_1^2+\tfrac{1}{4}a_1^2\cot^2\frac{180^\circ}{n}$, and $l=\left(\frac{a_1-a_3}{a_1}\right)l_1$;

whence l is known since l_1 is known in terms of h.

When the pyramid is irregular the lateral planes are non-congruent trapeziums, the areas of which can be found separately by § 12, and hence the whole surface.

§ 76. *Volume of the Frustum of a Triangular Prism.*—Let A denote the area of ABC (fig. 46), and let h_1, h_2, h_3 be the altitudes of A′, B′, C′ respectively with reference to the plane ABC. Divide the frustum into three pyramids B′A′AC, B′ABC, and B′A′CC′ by the planes B′AC and B′A′C. These three pyramids are respectively equal to BA′AC, B′ABC, and ABCC′;
hence volume of frustum $=\tfrac{1}{3}h_1\text{A}+\tfrac{1}{3}h_2\text{A}+\tfrac{1}{3}h_3\text{A}$
$=\tfrac{1}{3}\text{A}(h_1+h_2+h_3)$.

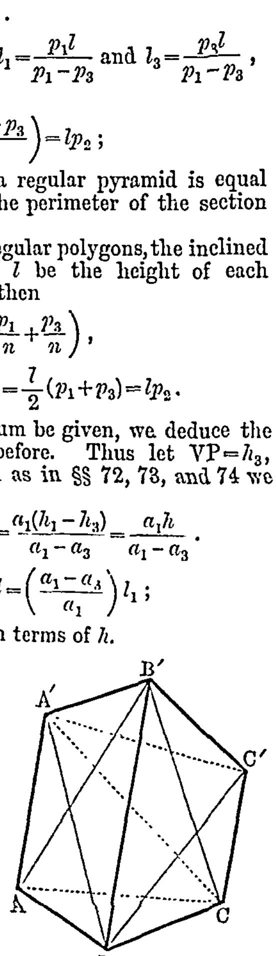


Fig. 46.

§ 77. If the prism be right or oblique, the volume of a frustum is equal to one-third of the area of its right section multiplied by the sum of the parallel edges. For divide the frustum AA′B′C′ (fig. 47) into two frusta by a plane A″B″C″ of area A at right angles to the edges, then

$$\text{AA}'\text{B}'\text{C}'=\text{AA}''\text{B}''\text{C}''+\text{A}''\text{A}'\text{B}'\text{C}'$$

$$=\tfrac{1}{3}\text{A}(\text{AA}''+\text{BB}''+\text{CC}'')+\tfrac{1}{3}\text{A}(\text{A}'\text{A}''+\text{B}'\text{B}''+\text{C}'\text{C}'')$$

$$=\tfrac{1}{3}\text{A}(\text{AA}''+\text{BB}''+\text{CC}''+\text{A}'\text{A}''+\text{B}'\text{B}''+\text{C}'\text{C}'')$$

$$=\tfrac{1}{3}\text{A}(\text{AA}'+\text{BB}'+\text{CC}')\,.$$

Again, since every prism can be divided into triangular prisms, we can find by repeated applications of the above proposition the volume of the frustum of any prism whatever. For example, if

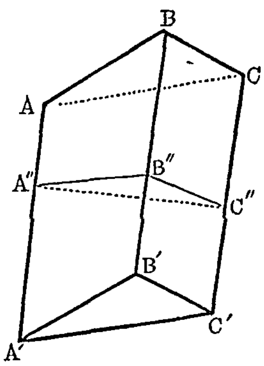


Fig. 47.

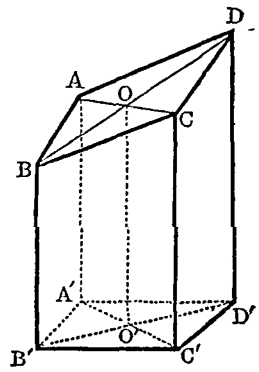


Fig. 48.

the base of the frustum of a right prism AA′B′C′D′ (fig. 48) be a rectangle 12 feet by 6 feet, and the parallel edges in order 6, 4, 10, and 12 feet, then

$$\text{A}=\text{area of base}=12\times 6=72\text{ square feet.}$$

$$\text{Frustum}=\text{ABCA}'\text{B}'\text{C}'+\text{ADCA}'\text{D}'\text{C}'$$

$$=\tfrac{1}{3}\times\tfrac{1}{2}\text{A}(\text{AA}'+\text{BB}'+\text{CC}')+\tfrac{1}{3}\times\tfrac{1}{2}\text{A}(\text{AA}'+\text{CC}'+\text{DD}')$$

$$=\tfrac{1}{6}\text{A}(2\text{AA}'+2\text{CC}'+\text{BB}'+\text{DD}')=576.$$

§ 78. *Volume of a Wedge.*—The wedge (fig. 49) being merely the frustum of a triangular prism, we have at once

$$\text{volume}=\tfrac{1}{3}\text{A}(\text{FE}+\text{AD}+\text{BC})\,,$$

where A is the area of its right section; otherwise, the wedge may be considered a prismatoid whose upper base is a straight line, and hence its volume $=\tfrac{1}{6}h(4\text{A}_2+\text{A}_3)$, since $\text{A}_1=0$.

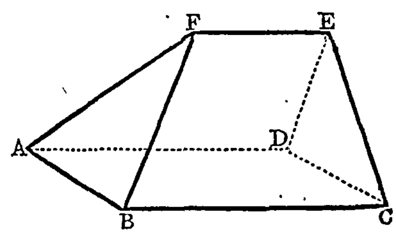


Fig. 49.

B. *Regular Polyhedra.*

§ 79. The regular polyhedra are five in number, namely, the *tetrahedron, cube, octahedron, dodecahedron,* and *icosahedron,* whose solid angles are formed respectively by three equilateral triangles, three squares, four equilateral triangles, three pentagons, and five equilateral triangles.

Since a regular polyhedron admits of having a sphere inscribed within it and described about it, it can easily be shown that the volume of the polyhedron

$$=a^3\times\frac{nl}{24}\times\frac{\cos\frac{\pi}{m}\cot^2\frac{\pi}{n}}{\left\{-\cos\left(\frac{\pi}{m}+\frac{\pi}{n}\right)\cos\left(\frac{\pi}{m}-\frac{\pi}{n}\right)\right\}^{\frac{1}{2}}}\,;$$

and from § 18, γ, it follows that the surface of the polyhedron

$$=a^2\times\frac{ln}{4}\cot\frac{\pi}{n}\,,$$

where $\quad l=$the number of faces,
$m=$the number of faces in each solid angle,
$n=$the number of edges in each face,
and $\quad a=$the length of each side.

The following table contains the surfaces and volumes for the five regular polyhedra whose edge is 1.

Polyhedron.	Surface.	Volume.
Tetrahedron	1·7320508	0·1178511
Cube	6·0000000	1·0000000
Octahedron	3·4641016	0·4714045
Dodecahedron	20·6457788	7·6631189
Icosahedron	8·6602540	2·1816950

The surface and volume of a regular polyhedron whose edge is a is obtained by multiplying the surface and volume of a similar polyhedron whose edge is 1 by a^2 and a^3 respectively.

Section II. Solids contained by Surfaces which are not all Planes.

A. *The Cylinder.*

§ 80. *Volume of a Cylinder* (fig. 50).—Inscribe in the cylinder a polygonal prism of which the number of sides may be increased indefinitely. Then in the limit the base of the prism becomes the base of the cylinder, and the volume of the prism the volume of the cylinder. Now by § 67 we have

$$\text{volume of prism} = \text{area of base} \times \text{altitude};$$

hence $$\text{volume of cylinder} = \text{area of base} \times \text{altitude}.$$

§ 81. *Surface of a Right Cylinder.*—As above, in the limit the base of the prism becomes the base of the cylinder, and the surface of the prism the surface of the cylinder. Now the lateral surface of prism

$= \text{perimeter of right section} \times \text{length}$

$= \text{perimeter of base} \times \text{length}$, in the case of a right prism (§ 68);

hence lateral surface of right cylinder = circumference of base × length.

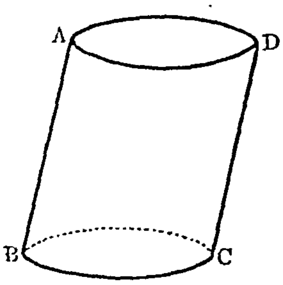


Fig. 50.

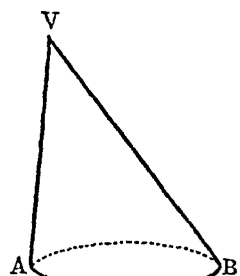


Fig. 51.

B. *The Cone.*

§ 82. *Volume of a Cone* (fig. 51).—Inscribe within the cone a pyramid of which the number of sides may be indefinitely increased, then in the limit the base of the pyramid becomes the base of the cone and the volume of the pyramid the volume of the cone.

By § 70 $\quad \text{volume of pyramid} = \frac{1}{3}\,\text{base} \times \text{altitude},$

and hence $\quad \text{volume of cone} = \frac{1}{3}\,\text{base} \times \text{altitude}.$

§ 83. *Volume of the Frustum of a Cone.*—From § 73 we find that the volume of the frustum of a pyramid

$$= \tfrac{1}{3}h(A_1 + \sqrt{A_1A_3} + A_3);$$

hence, since in the limit the frustum of the pyramid becomes the frustum of the cone, we have

$$\text{volume of conical frustum} = \tfrac{1}{3}h(A_1 + \sqrt{A_1A_3} + A_3),$$

where A_1 and A_3 are the areas of the terminating planes of the frustum.

Let the terminating planes be circles of radii r_1 and r_3, then volume of frustum

$$= \tfrac{1}{3}h(\pi r_1^2 + \pi r_1 r_3 + \pi r_3^2) = \tfrac{1}{3}\pi h(r_1^2 + r_1 r_3 + r_3^2).$$

Again, by the same section we have

$$\text{volume of frustum of pyramid} = \tfrac{1}{6}h(A_1 + 4A_2 + A_3),$$

therefore $\quad \text{volume of conical frustum} = \tfrac{1}{6}\pi h(r_1^2 + 4r_2^2 + r_3^2),$

where r_2 is the radius of the circular section parallel to the terminating planes and equidistant from them.

§ 84. *Surface of a Right Cone.*—The lateral surface of a regular pyramid is by § 71

$$= \tfrac{1}{2}\,\text{perimeter of base} \times \text{slant height};$$

hence, since in the limit the surface of the pyramid becomes the surface of the cone, the lateral surface of a right cone is equal to half the circumference of its base multiplied by the slant height.

Thus the lateral surface of a right cone of slant height l and the radius of whose base is r is equal to

$$\tfrac{1}{2} \times 2\pi r \times l = \pi r l,$$

and $\quad \text{whole surface} = \text{lateral surface} + \text{area of base}$

$$= \pi r l + \pi r^2$$
$$= \pi r(l + r).$$

Again, if h, the altitude of the cone, be given, we have

$$l = \sqrt{h^2 + r^2},$$

and therefore $\quad \text{whole surface} = \pi r(\sqrt{h^2 + r^2} + r).$

§ 85. *Surface of the Frustum of a Right Cone.*—The lateral surface of the frustum of a regular pyramid is equal to the product of the slant height and the perimeter of its middle section (§ 74); hence in the limit we find that the lateral surface of the frustum of a right cone is equal to the product of its slant height and the circumference of the section equidistant from its parallel faces.

Let r_1 and r_3 denote the radii of the ends of the frustum, and l the length of the slant height, then

$$r_2 = \tfrac{1}{2}(r_1 + r_3) = \text{radius of middle section},$$

and therefore

$$\text{lateral surface} = 2\pi r_2 \times l = 2\pi \times \tfrac{1}{2}(r_1 + r_3) \times l = \pi l(r_1 + r_3),$$

and $\quad \text{whole surface} = \pi r_1^2 + \pi l(r_1 + r_3) + \pi r_3^2.$

If h, the altitude of the frustum, be given, we have

$$l = \sqrt{h^2 + (r_1 - r_3)^2}.$$

C. *The Sphere.*

§ 86. *Surface of a Spherical Zone.*—Let AB (fig. 52) be a small arc of the sphere, and let AA′, BB′ be perpendicular to the axis XX′, to find the surface of the zone generated by the arc AB. Join AB, and draw OP perpendicular to AB, BD parallel to XX′, and PP′ parallel to AA′ or BB′. The chord AB generates the frustum of a cone, whose lateral surface $= 2\pi PP' \times AB$.

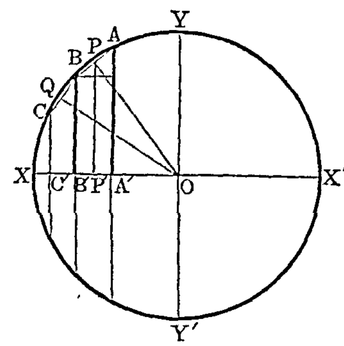


Fig. 52.

But, since the triangles ABD and OPP′ are similar,

$$\frac{AB}{BD} = \frac{OP}{PP'},$$

therefore $\quad \text{area of conical frustum} = 2\pi.OP.BD = 2\pi.OP.A'B'.$

Similarly $\quad$ the area of the frustum generated by $BC = 2\pi.OQ.B'C'$.

But in the limit when the chords AB, BC, &c., are indefinitely diminished, the perpendiculars OP, OQ, &c., become each $= r$, and hence by summing all the areas we get in the limit

$$\text{area of zone} = 2\pi r \times (\text{projection of arc on axis of revolution}).$$

Hence the convex surface of a segment of a sphere is equal to the circumference of a great circle multiplied by the height of the segment or zone.

§ 87. *Surface of a Sphere.*—The whole sphere being a zone whose height is $2r$, we obtain at once

$$\text{surface of sphere} = 2\pi r \times 2r = 4\pi r^2;$$

or the surface of a sphere is equal to four great circles.

The total surface of the cylinder circumscribing the sphere of radius r is $6\pi r^2$, hence the surface of the sphere $= \frac{2}{3}$ surface of circumscribing cylinder.

§ 88. *Surface of a Lune, a Spherical Triangle, and a Spherical Polygon.*—It is shown in spherical trigonometry that

(α) the area of a lune included between two great circles of a sphere of radius r, and whose inclination is θ radians, is

$$2\theta r^2;$$

(β) the area of a spherical triangle whose angles are A, B, C is

$$(A + B + C - \pi)r^2;$$

(γ) the area of a spherical polygon of r sides is

$$\{P - (r-2)\pi\}r^2, \text{ where P is the sum of its angles.}$$

§ 89. *Measurement of Solid Angles.*—A convenient unit for the measurement of plane angles is the "radian." If we assume that each unit of surface of a sphere subtends the same solid angle at the centre, we can deduce a very convenient unit for the measurement of solid angles. This unit, which has received the name "steradian," we define to be the solid angle subtended at the centre of a sphere by a portion of the surface whose area is r^2.

§ 90. *Number of Steradians in an Angle.*—Let A be the angle at the centre of a sphere, and let S be the portion of the surface of the sphere which it intercepts, then

$$\frac{\text{number of steradians in A}}{1} = \frac{S}{r^2}.$$

For example, if A be a plane solid angle, S = a hemisphere $= 2\pi r^2$; hence the number of steradians in a plane solid angle $= \dfrac{S}{r^2} = \dfrac{2\pi r^2}{r^2} = 2\pi$, and therefore the number of steradians in the solid angle at a point $= 4\pi$. This solid angle is sometimes called a steregon.

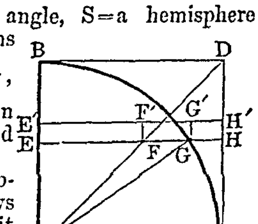


Fig. 53.

Hence, if we can find the surface subtended by any solid angle, we can always find its magnitude in terms of the unit solid angle.

§ 91. *Volume of a Sphere.*—Let ABC (fig. 53) be the quadrant of a circle, draw DB and DC tangents to it, then, if AD be joined and the whole figure be conceived as

rotating round AB, ABD, ABC, and ABDC will generate a cone, a hemisphere, and a cylinder respectively.

Now draw two parallel planes EFGH and E'F'G'H' very near each other and perpendicular to AB, and draw FF' and GG' parallel to AB, then, by § 80,

$$\begin{aligned} &\text{volume generated by EHH'E'} = \pi EH^2 \times EE', \\ &\quad ,, \qquad ,, \qquad EGG'E' = \pi EG^2 \times EE', \\ &\quad ,, \qquad ,, \qquad EFF'E' = \pi EF^2 \times EE'. \end{aligned}$$

Thus volume generated by EFF'E' + volume generated by EGG'E'

$$\begin{aligned} &= \pi(EF^2 + EG^2) \times EE' = \pi(EA^2 + EG^2) \times EE' \\ &= \pi(AG^2) \times EE' = \pi EH^2 \times EE' \\ &= \text{volume generated by EHH'E'}. \end{aligned}$$

Therefore in the limit, when the number of slices is indefinitely increased, and their thickness indefinitely diminished, we have volume of cone generated by AF + volume of spherical zone generated by CG = volume of cylinder generated by CH.

Let r = radius of sphere, h = AE = height of zone ACGE, then

$$\text{volume of cone} = \tfrac{1}{3}\pi h^2 \times h = \tfrac{1}{3}\pi h^3, \text{ and}$$

$$\text{volume of cylinder} = \pi r^2 \times h,$$

therefore $\quad$ volume of spherical zone $= \pi r^2 h - \tfrac{1}{3}\pi h^3$

$$= \tfrac{1}{3}\pi h(3r^2 - h^2).$$

The height of a hemisphere is r,

therefore $\quad$ volume of hemisphere $= \tfrac{1}{3}\pi r(3r^2 - r^2) = \tfrac{2}{3}\pi r^3$,

and $\quad$ volume of whole sphere $= \tfrac{4}{3}\pi r^3$,

a result readily obtainable by the infinitesimal calculus, or by inscribing within the sphere a series of triangular pyramids whose vertices all meet at the centre of the sphere, and the angles of whose bases all rest on the surface. In the limit the altitude of each pyramid becomes the radius of the sphere, and the sum of the bases of the pyramids the surface of the sphere; hence

$$\text{volume} = \tfrac{1}{3}S \times r = \tfrac{1}{3} \times 4\pi r^2 \times r = \tfrac{4}{3}\pi r^3.$$

The volume of the circumscribing cylinder $= \pi r^2 \times 2r = 2\pi r^3$,

therefore volume of sphere $= \tfrac{2}{3}$ volume of circumscribing cylinder.

§ 92. Let S denote the surface of a sphere and V its volume, then from §§ 87 and 91 we have

$$(\alpha)\ r = \frac{\sqrt{S}}{2\sqrt{\pi}} = \sqrt[3]{\frac{3}{4\pi}} \times \sqrt[3]{V};$$

$$(\beta)\ S = \sqrt[3]{\pi(6V)^2};$$

$$(\gamma)\ V = \frac{1}{6\sqrt{\pi}}\sqrt{(S)^3};$$

formulæ which give the radius in terms of the surface or volume, the surface in terms of the volume, and the volume in terms of the surface.

§ 93. *Volume of a Spherical Shell.*—Let r and r_1 denote the radii of the two spheres, then

$$\begin{aligned} \text{volume of shell} = V &= \tfrac{4}{3}\pi r_1^3 - \tfrac{4}{3}\pi r^3 \\ &= \tfrac{4}{3}\pi(r_1^3 - r^3) \\ &= \tfrac{4}{3}\pi(r_1 - r)(r_1^2 + r_1 r + r^2). \end{aligned}$$

Now let $r_1 - r = h$, then

$$V = \tfrac{4}{3}\pi r_1^2 h\left(1 + \frac{r}{r_1} + \frac{r^2}{r_1^2}\right).$$

If h be small compared with r_1, then r/r_1 is very nearly equal to 1, and we have approximately

$$V = \tfrac{4}{3}\pi r_1^2 h(1 + 1 + 1) = 4\pi r_1^2 h.$$

Again, if h be nearly equal to r_1, r is very small, and r/r_1 is also very small, so that we have approximately

$$V = \tfrac{4}{3}\pi r_1^2 h.$$

§ 94. *Volume of a Spherical Segment.*—Let CRC' (fig. 54) be a section of a spherical segment whose altitude RQ is p, then, if OQ $= h$, volume of segment CRC' = volume of hemisphere − volume of zone AA'C'C

$$\begin{aligned} &= \tfrac{2}{3}\pi r^3 - \tfrac{1}{3}\pi h\{3r^2 - h^2\}, \text{ § 91.} \\ &= \tfrac{2}{3}\pi r^3 - \tfrac{1}{3}\pi(r - p)\{3r^2 - (r - p)^2\} \\ &= \tfrac{1}{3}\pi p^2(3r - p). \end{aligned}$$

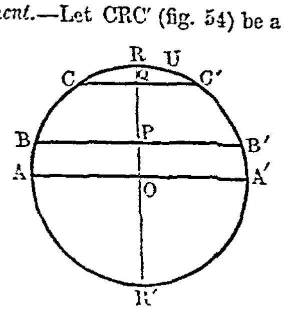


Fig. 54.

If we put $p = 2r$, we obtain as before volume of sphere $= \tfrac{4}{3}\pi r^3$.

Again if CQ $= a_1$ we have

$$CQ^2 = a_1^2 = RQ.R'Q = p(2r - p),$$

$$\text{whence } r = \frac{a_1^2 + p^2}{2p},$$

therefore $\quad$ volume of segment $= \tfrac{1}{6}\pi p(3a_1^2 + p^2)$.

§ 95. *Volume of a Spherical Frustum.*—When one of the terminating planes passes through the centre we have already found that the volume

$$= \tfrac{1}{3}\pi h(r^2 - h^2),$$

where h is its altitude.

Now suppose that neither of the terminating planes passes through the centre; for example, to find the volume of the frustum BB'C'C. Let RQ $= p$ and RP $= q$, then

$$\begin{aligned} BB'C'C &= \text{segment RBB'} - \text{segment RCC'} \\ &= \tfrac{1}{6}\pi q(3a_2^2 + q^2) - \tfrac{1}{6}\pi p(3a_1^2 + p^2), \end{aligned}$$

where a_1 and a_2 are the radii of the ends CC' and BB'.

Let $q - p = h$ = height of frustum, and, since, from the geometry of the figure,

$$\frac{a_1^2 + p^2}{p} = \frac{a_2^2 + q^2}{q} = 2r,$$

we have $\quad$ volume $= \tfrac{1}{6}\pi h\{3(a_1^2 + a_2^2) + h^2\}$,

a result which may also be obtained by considering BB'C'C as the difference of the two zones AA'C'C and AA'B'B.

D. *Spheroid.*

§ 96. *Surface of a Prolate Spheroid.*—The prolate spheroid is the solid generated by the revolution of an ellipse about its major axis. If S be the surface generated by an arc of the curve, then

$$S = 2\pi\int y\sqrt{1 + \left(\frac{dy}{dx}\right)^2}\,dx, \text{ taken between proper limits.}$$

In the case before us

$$S = 2\pi b^2 + 2\pi\frac{ab}{e}\sin^{-1}e,$$

where e is the eccentricity (INFINITESIMAL CALCULUS, art. 179).

§ 97. *Surface of an Oblate Spheroid.*—The oblate spheroid is the solid generated by the revolution of an ellipse about its minor axis (fig. 55).

Here surface $= 2\pi a^2 + \pi\dfrac{b^2}{e}\log_e\dfrac{1 + e}{1 - e}$ (INFINITESIMAL CALCULUS, art. 179).

§ 98. *Volume of a Spheroid.*—We have volume of prolate spheroid

$$= \pi\int_{-a}^{+a} b^2\left(1 - \frac{x^2}{a^2}\right)dx = 2\pi b^2\int_0^a\left(1 - \frac{x^2}{a^2}\right)dx = \tfrac{4}{3}\pi ab^2.$$

Similarly volume of oblate spheroid $= \tfrac{4}{3}\pi a^2 b$.

Thus,

$$(\alpha)\quad \frac{\text{volume of prolate spheroid}}{\text{volume of oblate spheroid}} = \frac{\tfrac{4}{3}\pi ab^2}{\tfrac{4}{3}\pi a^2 b} = \frac{b}{a};$$

$$(\beta)\quad \frac{\text{sphere described on major axis}}{\text{prolate spheroid}} = \frac{\tfrac{4}{3}\pi a^3}{\tfrac{4}{3}\pi ab^2} = \frac{a^2}{b^2};$$

$$(\gamma)\quad \frac{\text{sphere described on minor axis}}{\text{oblate spheroid}} = \frac{\tfrac{4}{3}\pi b^3}{\tfrac{4}{3}\pi a^2 b} = \frac{b^2}{a^2}.$$

§ 99. *Volume of a Segment of a Spheroid.*

(α) *The prolate spheroid.*—This segment is generated by the revolution of AMP (fig. 23, p. 20) about AM, and hence

$$\text{its volume} = \pi\int_0^h y^2dx = \pi\frac{b^2}{a^2}\int_0^h(2ax - x^2)dx = \frac{\pi}{3} \times \frac{b^2h^2}{a^2}(3a - h),$$

where A is the origin and AM $= h$.

(β) *The oblate spheroid.*—The segment in this case is generated by the revolution of BMP (fig. 55) about BC, and hence

$$\text{its volume} = \pi\int_0^h y^2dx = \pi\frac{a^2}{b^2}\int_0^h(2bx - x^2)dx = \frac{\pi}{3} \times \frac{a^2h^2}{b^2}(3b - h),$$

where B is the origin and BM $= h$.

§ 100. *Volume of the Frustum of a Spheroid when one of the Terminating Planes passes through the Centre.*

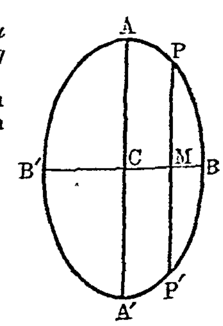


Fig. 55.

(α) *The prolate spheroid.*—The frustum in this case is generated by the revolution of BCMP about CM (fig. 23).

Now volume generated by BCMP

$$\begin{aligned} &= \text{volume generated by BCA} \\ &\quad - \text{volume generated by PMA} \\ &= \tfrac{2}{3}\pi ab^2 - \frac{\pi}{3} \times \frac{b^2h^2}{a^2}(3a - h) \\ &= \frac{\pi}{3} \times \frac{b^2k}{a^2}(3a^2 - k^2), \text{ where} \end{aligned}$$

k = CM = height of frustum $= a - h$.

(β) *The oblate spheroid.*—We can show in a similar manner that the volume generated in this case

$$= \frac{\pi}{3} \times \frac{a^2k}{b^2}(3b^2 - k^2).$$

The above formulæ may be put into another form. Thus, in the case of the prolate spheroid, since the point P lies on the ellipse $b^2x^2 + a^2y^2 = a^2b^2$, we have

$$b^2k^2 + a^2b_1^2 = a^2b^2, \text{ where } b_1 = PM, \text{ which gives}$$

$$k^2 = a^2\frac{(b^2 - b_1^2)}{b^2};$$

whence, by substitution, the volume of prolate frustum

$$=\tfrac{1}{3}\pi k(2b^2+b_1^2).$$

Similarly we can show that the volume of the oblate frustum

$$=\tfrac{1}{3}\pi k(2a^2+a_1^2),$$

where $a_1=\mathrm{PM}$.

These formulæ play an important part in the gauging of casks.

E. *Paraboloid.*

§ 101. *Surface of a Paraboloid.*—Let the equation to the parabola be $y^2=4ax$, and let the coordinates of P (fig. 21, p. 19) be x_1, y_1, then the surface of the paraboloid generated by the revolution of AM about AP

$$=2\pi\int_0^{x_1} y\sqrt{1+\left(\frac{dy}{dx}\right)^2}\,dx=4\pi\sqrt{a}\int_0^{x_1}\sqrt{x}\,\sqrt{\frac{x+a}{x}}\,dx$$
$$=\tfrac{8}{3}\pi\sqrt{a}\left\{(x_1+a)^{\frac{3}{2}}-a^{\frac{3}{2}}\right\}.$$

§ 102. *Volume of a Paraboloid.*—With the same notation we have

$$\text{volume}=\pi\int_0^{x_1}y^2dx=4\pi a\int_0^{x_1}x\,dx=\tfrac{1}{2}\pi\times 4ax_1\times x_1=\tfrac{1}{2}\pi y_1^2\times x_1\,;$$

or the volume of a paraboloid generated by the revolution of a part of a parabola between the vertex and any point is equal to half the volume of the circumscribing cylinder.

§ 103. If the coordinates of Q be x_2, y_2, then the volume of the frustum PP′Q′Q

$$=\tfrac{1}{2}\pi\left\{y_2^2x_2-y_1^2x_1\right\}=2\pi a(x_2^2-x_1^2)=\tfrac{1}{2}\pi(y_2^2+y_1^2)h\,,$$

where $h=\mathrm{MN}$; hence the volume of the frustum of a paraboloid is equal to half the sum of the areas of its ends multiplied by its height.

F. *Ellipsoid.*

§ 104. *Volume of an Ellipsoid.*—The equation to the ellipsoid being

$$\frac{x^2}{a^2}+\frac{y^2}{b^2}+\frac{z^2}{c^2}=1\,,$$

the equation to the elliptic section at the distance z from the origin is

$$\frac{x^2}{a^2}+\frac{y^2}{b^2}=1-\frac{z^2}{c^2}\,.$$

Now if we draw an indefinite number of parallel planes perpendicular to the axis of z, each slice will be an infinitely thin cylindrical plate, and accordingly the whole volume of the ellipsoid

$=\int A\,dz$, where A is the area of the elliptic section.

But $A=\pi ab\left(1-\dfrac{z^2}{c^2}\right)$, § 51,

therefore $\quad\text{volume}=\pi ab\displaystyle\int_{-c}^{c}\left(1-\frac{z^2}{c^2}\right)dz=\tfrac{4}{3}\pi abc$:

The sphere being an ellipsoid whose axes are all equal, we obtain as before

$$\text{volume of sphere}=\tfrac{4}{3}\pi a^3=\tfrac{4}{3}\pi r^3.$$

G. *Hyperboloid.*

§ 105. *Volume of an Hyperboloid.*—The hyperboloid is generated by the revolution of the hyperbolic segment ANP about AN (fig. 24, p. 20). If the coordinates of P be x_1, y_1, then

$$\text{volume of hyperboloid}=\pi\int_a^{x_1}y^2dx=\pi\frac{b^2}{a^2}\int_a^{x_1}(x^2-a^2)dx$$
$$=\pi\frac{b^2}{a^2}\left\{\frac{x_1^3}{3}-a^2x_1+\frac{2a^3}{3}\right\}=\frac{\pi b^2h^2}{3a^2}(3a+h)\,,$$

where $h=\mathrm{AN}=x_1-a$.

Again, since x_1, y_1 is on the curve, we have

$a^2y_1^2-b^2(a+h)^2=-a^2b^2$, which gives $\dfrac{b^2}{a^2}=\dfrac{y_1^2}{2ah+h^2}$; whence

$$\text{volume of hyperboloid}=\frac{\pi hy_1^2}{3}\times\frac{3a+h}{2a+h}\,.$$

H. *Solids to which the "Prismoidal Formula" applies.*

§ 106. It was shown in § 72 that the volume of any polyhedron bounded by two parallel planes and by plane rectilinear figures

$$=\tfrac{1}{6}h(A_1+4A_2+A_3),$$

where A_1, A_3, and A_2 denote respectively the areas of the two ends and of the middle section.

We now proceed to show that the same formula determines the volumes of all solids bounded by two parallel planes, provided the area of any section parallel to these planes can be expressed as a rational integral algebraic function of the third degree in x, where x is the distance of the section from either plane.

Let $\phi(x)=A+Bx+Cx^2+Dx^3+\;.\;.\;.\;.\;+Kx^n$ denote the area of the section in question.

Now the solid between the sections $\phi(0)$ and $\phi(4)$ is equal to the solid between the sections $\phi(0)$ and $\phi(2)$ plus the solid between the sections $\phi(2)$ and $\phi(4)$. Hence if the prismoidal formula is to hold in this case, we have

$$\tfrac{1}{6}h\{\phi(0)+4\phi(2)+\phi(4)\}$$
$$=\tfrac{1}{12}h\{\phi(0)+4\phi(1)+\phi(2)\}+\tfrac{1}{12}h\{\phi(2)+4\phi(3)+\phi(4)\}\,,$$

where h is the distance between the sections $\phi(0)$ and $\phi(4)$. Hence we have

$$\phi(0)-4\phi(1)+6\phi(2)-4\phi(3)+\phi(4)=0\,.$$

Now
$$\begin{aligned}
&\phi(0)=A\\
-&4\phi(1)=-4A-4B-4C-4D-4E-\;.\;.\;.\;.\;-4K\\
+&6\phi(2)=6A+12B+24C+48D+96E+\;.\;.\;.\;.\;+6\cdot 2^nK\\
-&4\phi(3)=-4A-12B-36C-108D-324E-\;.\;.\;.\;.\;-4\cdot 3^nK\\
+&\;\;\phi(4)=A+4B+16C+64D+256E+\;.\;.\;.\;.\;+4^nK.
\end{aligned}$$

Therefore $\quad 0=0+0+0+0+24E+PF+\;.\;.\;.\;.\;+TK.$

Hence $E=F=\;.\;.\;.\;.\;K=0$, and therefore $\phi(x)$ must be a function of the third degree in order that the prismoidal formula may apply.

§ 107. If we take $\phi(x)=A+Bx+Cx^2+Dx^3$, there will be as many possible varieties as there are combinations of four things, one, two, three, and four together, *i.e.*, $2^4-1=15$ varieties. Corresponding to each of these there will be *at least one solid* the area of a section of which at a distance x from one of the parallel planes is $\phi(x)=A+Bx+Cx^2+Dx^3$, and *at least one solid of revolution* generated by the curve whose equation is of the form

$$\pi y^2=\phi(x)=A+Bx+Cx^2+Dx^3\,.$$

As space prevents us discussing all the cases that may arise, we content ourselves by giving three examples as illustrations.

(α) *Volume of an ellipsoid.*—Here $\phi(x)=Bx+Cx^2$.

Let $2a$, $2b$, and $2c$ be the axes of which $2a$ is the greatest, then $h=2a$, $A_1=0_1$, $A_3=0$, and $A_2=\pi bc$;

therefore $\quad\text{volume}=\tfrac{1}{6}h(A_1+4A_2+A_3)=\tfrac{2}{6}a(4\pi bc)=\tfrac{4}{3}\pi abc$,

which agrees with the result in § 104.

(β) *Volume of a sphere.*—Here $\pi y^2=\phi(x)=Bx+Cx^2$.

Let r be the radius of the sphere, then $h=2r$, $A_1=0$, $A_3=0$, and $A_2=\pi r^2$, hence, as before (§ 91),

$$\text{volume of sphere}=\tfrac{1}{6}h(A_1+4A_2+A_3)=\frac{2r}{6}(4\pi r^2)=\tfrac{4}{3}\pi r^3.$$

(γ) *Volume of a right circular cone.*—Here $\pi y^2=\phi(x)=Cx^2$.

Let r = radius of base and h the altitude, then $A_1=0$, $A_3=\pi r^2$, and $A_2=\pi(\frac{1}{2}r)^2$; hence

$$\text{volume of cone}=\tfrac{1}{6}h\{A_1+4A_2+A_3\}=\tfrac{1}{6}h\{\pi r^2+\pi r^2\}=\tfrac{1}{3}h\pi r^2$$

In a similar manner we can determine the volumes of a cylinder, a prolate spheroid, an oblate spheroid, &c.

§ 108. In general, if in any solid we have

$$\phi(x)=A+Bx+Cx^2+Dx^3,$$

where A, B, C, and D are known constants, then, if h be the length of the solid,

$$\begin{aligned}
A_1&=\phi(0)=A,\\
A_2&=\phi(\tfrac{1}{2}h)=A+B(\tfrac{1}{2}h)+C(\tfrac{1}{2}h)^2+D(\tfrac{1}{2}h)^3,\\
A_3&=\phi(h)=A+Bh+Ch^2+Dh^3,
\end{aligned}$$

and therefore

$$\begin{aligned}
\text{volume of solid}&=\tfrac{1}{6}h(A_1+4A_2+A_3)\\
&=Ah+\tfrac{1}{2}Bh^2+\tfrac{1}{3}Ch^3+\tfrac{1}{4}Dh^4.
\end{aligned}$$

I. *Solids of Revolution in General.*

§ 109. *Volume of any Solid of Revolution.*—Let $P_1P_2\;.\;.\;.\;.\;P_n$ (fig. 34) be the generating curve, and $A_1\;.\;.\;.\;.\;A_n$ the axis of revolution. Divide the curve into portions in the points P_2, P_3, &c., and draw the chords and tangents of the small arcs P_1P_2, P_2P_3, &c., then it is evident that the solid generated by the curve is greater than the sum of the conical frusta traced out by the chords and less than the sum of the conical frusta traced out by the tangents. Hence, by increasing the number of chords, namely, by increasing the points of division of the curve, we can make the difference between these sums as small as we please, and therefore by this method we can approximate as closely as we please to the volume of the solid generated.

Assuming that the points P_1, P_2, P_3 are so near each other that the solid generated differs little from the frustum of a cone, and using the same notation as in § 63, we have volume generated by

$$\begin{aligned}
P_1P_2P_3&=\tfrac{1}{6}\pi A_1A_3(s_1^2+4s_2^2+s_3^2)=\tfrac{1}{6}\pi 2A_1A_2(s_1^2+4s_2^2+s_3^2)\\
&=\tfrac{1}{3}\pi a(s_1^2+4s_2^2+s_3^2)\,;
\end{aligned}$$

similarly the volume generated by

$$P_3P_4P_5=\tfrac{1}{3}\pi a(s_3^2+4s_4^2+s_5^2)\,;$$

whence the volume generated by the whole curve $P_1P_2\;.\;.\;.\;.\;P_n$

$$=\tfrac{1}{3}\pi a\left\{s_1^2+s_n^2+2(s_3^2+s_5^2+\;.\;.\;.\;.\;+s_{n-2}^2)+4(s_2^2+s_4^2+\;.\;.\;.\;.\;+s_{n-1}^2)\right\};$$

or (since $\pi s_1^2 = \frac{c_1^2}{4\pi}$, $\pi s_2^2 = \frac{c_2^2}{4\pi}$, &c.)

$$= \frac{1}{\pi}\frac{a}{12}\{c_1^2 + c_n^2 + 2(c_3^2 + c_5^2 + \ldots + c_{n-2}^2) + 4(c_2^2 + c_4^2 + \ldots + c_{n-1}^2)\},$$

a formula more convenient in practice, as it is sometimes more easy to measure equidistant circumferences than equidistant radii.

J. *Theorems of Pappus.*

§ 110. The following general propositions concerning surfaces and solids of revolution, usually called Guldin's theorems, are worth the reader's attention.

If any plane curve revolve about any external axis situated in its plane, then

(α) the surface of the solid which is thereby generated is equal to the product of the perimeter of the revolving curve and the length of the path described by the centre of gravity of that perimeter;

(β) the volume of the solid is equal to the product of the area of the revolving curve and the length of the path described by the centre of gravity of the revolving area.

We content ourselves with an example or two of the application of these theorems, referring to the article INFINITESIMAL CALCULUS for the proofs.

Example 1.—To find the surface and volume of a circular ring.—Let a be the distance of the centre of the generating curve, in this case a circle, from the axis of rotation, and r the radius of the circle, then

$$\text{perimeter of generating curve} = 2\pi r,$$
$$\text{area of generating curve} = \pi r^2, \text{ and}$$

path described by the centre of gravity either of the perimeter or area $= 2\pi a$; hence

$$\text{surface of ring} = 2\pi r \times 2\pi a = 4\pi^2 ra, \text{ and}$$
$$\text{volume of ring} = \pi r^2 \times 2\pi a = 2\pi^2 r^2 a.$$

Example 2.—To find the volume swept out by an ellipse whose axes are $2a$ and $2b$, revolving about an axis in its own plane whose distance from the centre of the ellipse is c.

Here area of generating curve $= \pi ab$,
and path described by centre of gravity of area $= 2\pi c$; hence

$$\text{volume generated} = \pi ab \times 2\pi c = 2\pi^2 abc.$$

Example 3.—A circle of r inches radius, with an inscribed regular hexagon, revolves about an axis a inches distant from its centre, and parallel to a side of the hexagon; to find the difference in area of the generated surfaces and volumes.

$$\text{Here perimeter of circle} = 2\pi r,$$
$$\text{and perimeter of hexagon} = 12 \times r \sin 30° \text{ (§ 17)}$$
$$= 6r;$$
$$\text{also area of circle} = \pi r^2,$$
$$\text{and area of hexagon} = 3r^2 \sin 60° \text{ (§ 18, } \beta)$$
$$= \tfrac{3}{2}\sqrt{3}r^2;$$

hence difference of surfaces generated

$$= 4\pi^2 ra - 12\pi ar = 4\pi ar(\pi - 3);$$

and difference of volumes generated

$$= 2\pi^2 r^2 a - 3\pi r^2 \sqrt{3} a$$
$$= \pi r^2 a(2\pi - 3\sqrt{3}).$$

PART III. GAUGING.

§ 111. By gauging is meant the art of measuring the volume of a cask, or any portion of it. The subject is one of great interest and practical importance, but space will only permit us to discuss it very briefly. If the cask whose capacity we wish to determine be a solid of revolution, then its volume can at once be computed, either exactly or approximately, by the methods already described.

It is usual to divide casks into the following four classes according to the nature of the revolving curve:—

(α) the middle frustum of a spheroid;
(β) the middle frustum of a parabolic spindle;
(γ) two equal frusta of a paraboloid, united at their bases;
(δ) two equal frusta of a cone, united at their bases.

Casks of the second, third, and fourth variety are rarely met with in practice, and we shall accordingly confine our attention to the first kind, which is considered the true or model form of cask.

Let ABCD (fig. 56) be a section of the cask, and assume it to be the middle frustum of a prolate spheroid, then

$$\text{its volume} = \tfrac{1}{3}\pi(2b^2 + b_1^2)k,$$

where $b = OY$, $b_1 = AX$, and $k = XX'$ (§ 99).

YY′ is called the bung diameter, and AB or CD the head diameter.

An imperial gallon contains 277·274 cubic inches, and therefore the number of gallons in the above cask

$$= \frac{\pi(2b^2 + b_1^2)k}{3 \times 277{\cdot}274} = \frac{\pi}{831{\cdot}822}(2b^2 + b_1^2)k.$$
$$= \left(\frac{2d^2 + d_1^2}{1059{\cdot}1}\right)k, \text{ where } d = 2b,\ d_1 = 2b_1;$$

whence we have the rule:—to the square of the head diameter add twice the square of the bung diameter, multiply the sum by the length and divide the result by 1059·1, and the answer is the content in imperial gallons.

Casks as ordinarily met with are not true spheroidal frusta, but it is better to consider them as such, calculate their capacity on this assumption, and then make allowance for the departure from the spheroidal form. The determination of the proper allowance to be made in each case is a matter depending on the skill and experience of the gauger, and proficiency in the art can only be attained by considerable practice.

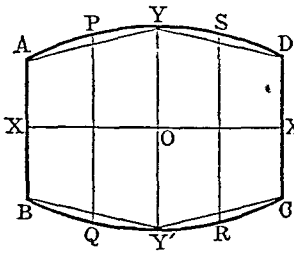


Fig. 56.

§ 112. If the cask be very little curved, we obtain an approximation to its capacity by considering it as made up of two equal frusta of a cone, united at their bases. Hence from § 83 we have

$$\text{volume of cask} = \tfrac{1}{3}\pi h(r_1^2 + r_1 r_3 + r_3^2) \text{ nearly.}$$

Here we neglect the small volumes generated by APY, YSD, BQY′, and Y′RC; and therefore the volume is too small.

If we put $r_1 r_3 = r_1^2$ we obtain

$$\text{volume} = \tfrac{1}{3}\pi h(2r_1^2 + r_3^2),$$

which is a little too large, and therefore the true volume lies between these two limits, and a very close approximation to it is said to be given by the formula

$$\tfrac{1}{3}\pi h\{2r_1^2 + r_3^2 - \tfrac{1}{3}(r_1^2 - r_3^2)\}.$$

§ 113. *Ullage of a Cask.*—The quantity of liquor contained in a cask partially filled and the capacity of the portion which is empty are termed respectively the wet and dry ullage.

(α) *Ullage of a standing cask.*—By means of the method applied in § 105, the following rule is deduced:—

Add the square of the diameter at the surface, the square of the diameter at the nearest end, and the square of double the diameter half-way between; multiply the sum by the length between the surface and the nearest end, and by ·000472.

The product will be the wet or dry ullage according as the lesser portion of the cask is filled or empty.

(β) *Ullage of a lying cask.*—The ullage in this case is found approximately on the assumption that it is proportional to the segment of the bung circle cut off by the surface of the liquor. The rule adopted in practice is

$$\text{ullage} = \tfrac{4}{5} \text{ content} \times \text{segmental area.}$$

(W. T.*)

MENTAL DISEASES. See INSANITY.

MENTON (Ital., *Mentone*), a cantonal capital in the department of Alpes-Maritimes, France, situated 15 miles north-east of Nice, on the shores of the Mediterranean. The town, which has a population of about 8000, rises like an amphitheatre on a promontory by which its semicircular bay (5 miles wide at its entrance, and bounded on the W. by Cape Martin and on the E. by the cliffs of La Murtola) is divided. It is composed of two very distinct portions: below, along the sea-shore, is the town of hotels and of foreigners, which alone is accessible to wheeled vehicles; above is that of the native Mentonese, with steep, narrow, and dark streets, spread over and clinging to the mountain, around the strong castle which was once its protection against the attacks of pirates. Facing the south-east, and sheltered on the north and west by high mountains, the Bay of Menton enjoys a delicious climate, and is on this account much frequented by invalids requiring a mild and equable temperature. The mean for the year is 61° Fahr., exceeding that of Rome or of

Pisa, and equalling that of Naples. Frost occurs on the average only once in ten years; in one particular year the thermometer did not fall below 46° Fahr. In summer the heat is never very great, the temperature rarely exceeding 86° Fahr. Winter and summer are the most agreeable seasons; in autumn the rain storms are accompanied by sudden changes of temperature, and in spring the sea breezes are apt to be violent. Besides the charms of its climate, Menton offers those of an almost tropical vegetation. Lemon-trees, olive-trees, and pines, rising above each other in successive stages, adorn the surrounding slopes. The district produces forty millions of lemons yearly, and this is the principal source of its natural wealth. The olive-trees are remarkable for the great size they have attained in the course of the centuries during which they have continued to bear. Of their wood a multitude of fancy objects are made for sale to strangers.

The origin of Menton is unknown. During the Middle Ages it was successively occupied by the Saracens, the Genoese, and the princes of Anjou. In the middle of the 14th century it was purchased as a single domain by the Grimaldis, lords of Monaco. During the times of the republic and the first empire it belonged to France; but in 1815 it again became the property of the princes of Monaco, who subjected it to such exactions that in 1848 its inhabitants, weary of finding their reasonable demands put off with empty promises, proclaimed their town free and independent, under the protection of Sardinia. Menton, with the neighbouring commune of Roquebrune, was united to France in 1860, at the same time as Nice and Savoy.

MENTZ. See MAINZ.

MENZEL, WOLFGANG (1798–1873), poet, critic, and historian, was born June 21, 1798, at Waldenburg in Silesia, studied at Breslau, Jena, and Bonn, and after living for some time in Aarau and Heidelberg finally settled in Stuttgart, where, from 1830 to 1838, he had a seat in the Würtemberg "landtag." His first work, a clever and original volume of poems, entitled *Streckverse* (Heidelberg, 1823), was followed in 1824–25 by a popular *Geschichte der Deutschen* in three volumes, and in 1829 and 1830 by *Rübezahl* and *Narcissus*, the ballads upon which his reputation as a poet chiefly rests. In 1851 he published the romance of *Furore*, a lively picture of the period of the Thirty Years' War; his other very numerous writings include *Geschichte Europa's*, 1789–1815 (1853), and histories of the German war of 1866 and of the Franco-German war of 1870–71. From 1825 to 1848 Menzel edited a "Literaturblatt" in connexion with the *Morgenblatt*; in the latter year he transferred his allegiance from the Liberal to the Conservative party, and in 1852 his "Literaturblatt" was again revived in that interest. In 1866 his political sympathies again changed, and all his energies were employed to oppose the "particularism" of the Prussian "junkers" and the antiunionism of South Germany. He died on April 23, 1873. His large private library of 18,000 volumes was afterwards acquired for the university of Strasburg.

MEPHISTOPHELES, the name of one of the personifications of the principle of evil. In old popular books and puppet-plays the word appears in various forms,—as Mephistopheles, Mephistophiles, Mephistophilis, and Mephostophilis. In the *Tragical History of Doctor Faustus*, Marlowe writes "Mephistophilis"; in the *Merry Wives of Windsor* we find "Mephistophilus." The etymology of the word is uncertain. According to one theory, it may be taken to represent μηφωστοφίλης; in which case the meaning would be "one who loves not light." Another theory is that the word is a combination of the Latin "mephitis" and the Greek φίλος, signifying "one who loves noxious exhalations." Probably it is of Hebrew origin,—from מֵפִיר, a destroyer, and טֹפֶל, taken to mean a liar. This view is supported by the fact that almost all the names of devils in the magic-books of the 16th century spring from the Hebrew. In the old Faust legends the character of Mephistopheles is simply that of a powerful and wicked being who fulfils Faust's commands in order to obtain possession of his soul. Marlowe attributes to him a certain dignity and sadness, and there can be little doubt that the Mephistophilis of the *Tragical History* suggested some important traits of Milton's Satan. The name has been made famous chiefly by Goethe, whose conception of the character varied at different periods of his career. In the fragment of *Faust* published in 1790, but written many years before, Mephistopheles has a clearly marked individuality; he is cynical and materialistic, but has a man's delight in activity and adventure, and his magical feats alone remind us that he is preternatural. In revising and extending this fragment, which forms the chief portion of the first part of *Faust*, Goethe treated Mephistopheles as the representative of the evil tendencies of nature, especially of the tendency to denial for its own sake, rather than as a living person. This character Mephistopheles maintains in the second part, where, indeed, the name often stands for a pure abstraction.

See Julius Mosen, *Faust*; Düntzer, *Erläuterungen zu Goethe's Werken: Faust*; Vischer, *Goethe's Faust*.

MEQUINEZ (the Spanish form of the Arabic *Miknása*), a town of Morocco, the ordinary residence of the emperor, is situated in a fine hilly country about 70 miles from the west coast and 35 west-south-west of Fez on the road to Sallee, in 34° N. lat. and 5° 35′ W. long. The town-wall, with its four-cornered towers, is kept in good condition; and a lower wall of wider circuit protects the luxuriant gardens with which the outskirts are embellished. In the general regularity of its streets, and in the fairly substantial character of its houses, Mequinez ranks higher than any other town in Morocco; but it possesses few buildings of any note, except the palace, and the mosque of Mulei Ismael, which serves as the royal burying-place. At one time the palace (founded in 1634) was an imposing structure, but the finest part has been allowed to go to ruin. In 1721 Windhus described it as "about 4 miles in circumference, the whole building exceeding massy, and the walls in every part very thick; the outward one about a mile long and 25 feet thick." The best part consisted of oblongs enclosing large open courts or gardens. Mortar or concrete was the principal material used for the walls, but the pillars were in many cases marble blocks of great beauty and costliness (*A Journey to Mequinez*, London, 1725). Most of the inhabitants of Mequinez are connected more or less directly with the court. Their number has been very variously estimated by different travellers. Gråberg de Hemsö gives 56,000 in 1834, Rohlfs in 1861 from 40,000 to 50,000, and Conring in 1880 about 30,000. The town was formerly called Tákarart. Edrisi refers the present name to a Berber chief Meknás.

MERAN, a favourite health resort, and the capital of a district in South Tyrol, Austria, is picturesquely situated at the foot of the vine-clad Küchelberg, on the right bank of the Passer, about half a mile above its junction with the Adige, and 45 miles to the south of Innsbruck. Meran proper consists mainly of one long narrow street, called the Laubengasse, flanked by covered arcades. In a wider sense, the name is often used to include the adjacent villages of Untermais, Obermais, and Gratsch. The most noteworthy buildings are the Gothic church of St Nicholas, with its lofty tower, dating from the 14th and 15th centuries; the Spitalkirche, built in the 15th century, and restored in 1880; and the quaint old Fürstenhaus, or residence of the counts of Tyrol. The town contains a gymnasium, a nunnery and school for girls, an institution for sick priests, and several other charitable establishments.

Meran owes its high reputation as a resort for consumptive and nervous invalids to the purity of its air and its comparative immunity from wind and rain in winter. It stands in 46° 41′ N. lat., at a height of 1050 feet above the sea, and has a mean annual temperature of about 54° Fahr. Meran enjoys three seasons, being also visited in spring for the whey-cure and in autumn for the grape-cure. The arrangements for the comfort of the visitors are very complete; and the environs afford opportunity for numerous pleasant walks and excursions. The favourite promenade of the inhabitants is on a massive dyke, built to protect the town against the encroachments of the Passer. Nearly twenty old castles and chateaus are visible from the bridge over the Passer, the most interesting being Schloss Tyrol, an ancient edifice which has given its name to the entire country. Meran is now frequented by about 6500 patients and 8000 to 9000 passing travellers annually. In 1880 its population, including Obermais and Untermais, amounted to 5334 souls.

Meran is probably the representative of the Roman Urbs Majensis, afterwards known as Mairania. It became a town in 1290, and down to 1490 was the capital of the counts and dukes of Tyrol. The town suffered somewhat during the Peasants' War in the 16th century, and subsequently from destructive floods. As a health-resort it has been known for about forty years. The whole region in which it lies is singularly rich in historic interest.

Authorities.—Beda Weber, *Meran*; Düringsfeld, *Aus Meran*, 1868; Noë, *Der Frühling von Meran*; Stampfer, *Chronik von Meran*, 1867, and *Geschichte der Stadt Meran*, 1872; Pircher, *Meran als Klimatischer Kurort*, 1870; Plant, *Führer durch Meran*, 2d ed., 1879; Knoblauch, *Meran*, 5th ed., 1881.

MERCATOR, GERARDUS (Latinized form of Gerhard Krämer) (1512–1594), mathematician and geographer, was born at Rupelmonde in Flanders, May 5, 1512. Having completed his studies at Louvain, he devoted himself to geography, and, after being for some time attached to the household of Charles V., he was appointed cosmographer to the duke of Juliers and Cleves in 1559, taking up his residence at Duisburg, where he died December 2, 1594. One of his earliest cartographical works was a terrestrial globe (1541), followed in 1551 by a celestial globe. In 1552 he published a treatise *De usu annuli astronomici* (Louvain), and at Cologne in 1569 his *Chronologia, hoc est temporum demonstratio . . . ab initio mundi usque ad Annum Domini* 1568, *ex eclipsibus et observationibus astronomicis, sacris quoque Bibliis*, &c. In the same year was published the first map on Mercator's well-known projection, with the parallels and meridians at right angles, for use in navigation. At Cologne, in 1578, appeared his *Tabulæ geographicæ ad mentem Ptolemæi restitutæ et emendatæ*. The work by which he is chiefly known is his atlas, published in 1594 at Duisburg, in folio, under the title of *Atlas, sive Cosmographicæ meditationes de fabrica mundi.* It contains, besides the maps, cosmographical and other dissertations, some of the theological views in which were condemned as heretical; it was completed by Hondius in 1607. Several of the maps had been previously published separately, the atlas being delayed to allow Ortelius to complete his. Mercator also published in 1592 a *Harmonia Evangeliorum.*

MERCURIAL AIR-PUMP. This name is given to two distinct instruments, one of which is founded on statical, the other on hydrodynamical principles.

1. *The Statical Pump.*—The famous spiritualist Swedenborg was the first to conceive an air-pump in which a mass of mercury, by being made to rise and fall alternately within a vertical vessel, should do the work which in the ordinary instrument is assigned to the piston. He published a description of his pump in 1722; but it is questionable whether his design was ever realized. Of numerous subsequent inventions the only one which, in fact, has survived is the admirably simple and yet efficient instrument first described in 1858, but constructed some time before, by H. Geisler of Bonn, which at once, and justly, met with universal acceptance.

The general scheme of Geisler's pump is shown in fig. 1. A and B are pear-shaped glass vessels connected by a long narrow india-rubber tube, which must be sufficiently strong in the body (or strengthened by a linen coating) to stand an outward pressure of 1 to 1½ atmospheres. A terminates below in a narrow vertical tube *c*, which is a few inches longer than the height of the barometer, and to the lower end of this tube the india-rubber tube is attached which connects A with B. To the upper end of A is soldered a glass two-way stop-cock, by turning which the vessel A can either be made to communicate through *s* and a hole in the hollow cock with the vessel to be exhausted (I., fig. 2), or through *g* with the atmosphere (II., fig. 2), or can be shut off from both when the cock holds an intermediate position. The apparatus, after having been carefully cleaned and dried, is charged with pure and dry mercury, which must next be worked backwards and forwards between A and B to remove all the air-bells. The air is then driven out of A by lifting B to a sufficient level, turning the cock into position II., and letting the mercury flow into A until it gets to the other side of the stop-cock, which is then placed in the intermediate position. Supposing the vessel to be exhausted to have already been securely connected with *b*, we now lower the reservoir B so as to reduce the pressure in A sufficiently below the tension in the gas to be sucked in, and, by turning the cock into position I., cause the gas to expand into and almost fill A. The cock is now shut against both *a* and *b*, the reservoir lifted, the gas contents of A discharged through *a*, and so on, until, when after an exhaustion mercury is let into A, the metal strikes against the top without interposition of a gas-bell. In a well-made apparatus the pressure in the exhausted vessel is now reduced to $\frac{1}{10}$ or $\frac{1}{20}$ of a millimetre, or even less. An absolute vacuum cannot be produced on account of the unavoidable air-film between the mercury and the walls of the apparatus.

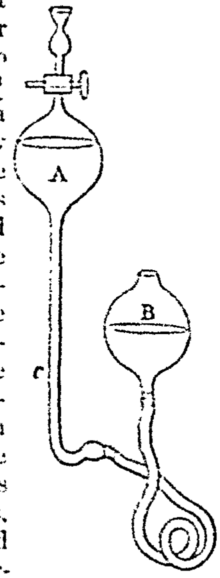


FIG. 1.—Geisler's Mercurial Air-Pump.

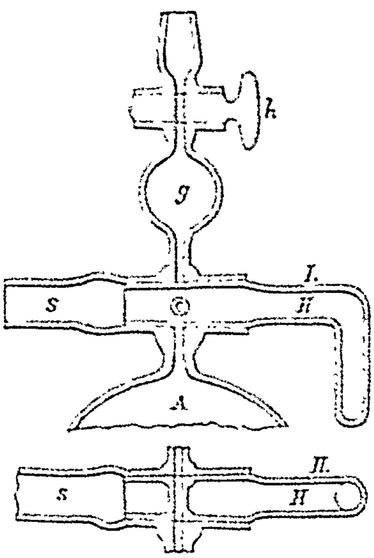


FIG. 2.—Arrangements of Stop-Cock in Air-Pump.

The great advantage of the mercurial over the ordinary air-pump is that it evacuates far more completely than the latter, that it affords direct and unmistakable evidence of the exhaustiveness of its work, and—last not least—that it enables one to transfer the gas sucked out to another vessel without loss or contamination, so that it can be measured and analysed. On account of this latter feature more especially, the instrument is highly valued as an auxiliary in gasometric researches. Without it the researches on which rests our present knowledge of the gases of the blood could not have been carried out. The actual instrument, as constructed for various kinds of work, has of course various complexities of detail omitted in the above description. For these the reader must refer to handbooks of practical physiology.

As it takes a height of about 30 inches of mercury to balance the pressure of the atmosphere, a Geisler pump necessarily is a somewhat long-legged and unwieldy instrument. It can be considerably shortened, the two vessels A and B brought more closely together, and the somewhat objectionable india-rubber tube be dispensed with, if we connect the air-space in B with an ordinary air-pump, and by means of it do the greater part of the sucking and the whole of the lifting work. An instrument thus modified was constructed by Poggendorff (see his *Annalen*, vol. cxxv. p. 151, 1865), and another, on somewhat different principles, by Prof. Dittmar (see the "*Challenger*" *Reports*).

Even a Geisler's stop-cock requires to be lubricated to be absolutely gas-tight, and this occasionally proves a nuisance. Hence a number of attempts have been made to do without stop-cocks altogether. In Töpler's pump[1] this is attained by using both for the inlet and the outlet vertical capillary glass tubes, soldered, the former to somewhere near the bottom, the latter to the top of the vessel. These tubes, being more than 30 inches high, obviously act as efficient mercury-traps; but the already considerable height of the pump is thus multiplied by two. This consideration has led Alexander Mitscherlich (*Pogg. Ann.*, cl. 420, 1873), and quite lately F. Neisen (*Z. f. Instrumentenkunde*, 1882, p. 285) to introduce glass valves in lieu of stop-cocks. As glass floats on mercury, such valves do not necessarily detract from the exhaustive power of the pump.

2. *The Dynamic Pump.*—This was invented in 1865 by H. Sprengel. The instrument, in its original (simplest) form (fig. 3), consists of a vertical capillary glass tube *a* of about 1 mm. bore, provided with a lateral branch *b* near its upper end, which latter, by an india-rubber joint governable by a screw-clamp, communicates with a funnel. The lower end is bent into the shape of a hook, and dips into a pneumatic trough. The vessel to be exhausted is attached to *b*, and, in order to extract its gas contents, a properly regulated stream of mercury is allowed to fall through the vertical tube. Every drop of mercury, as it enters from the funnel, entirely closes the narrow tube like a piston, and in going past the place where the side tube enters entraps a portion of air and carries it down to the trough, where it can be collected. If the vertical tube, measuring from the point where the branch comes in, is a few inches greater than the height of the barometer, and the glass and mercury are perfectly clean, the apparatus slowly but surely produces an almost absolute vacuum.

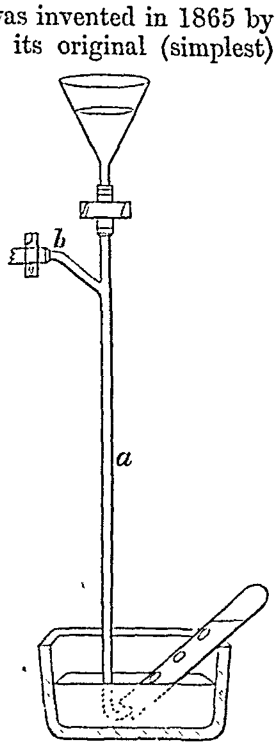


FIG. 3.—Sprengel's Air-Pump.

The great advantages of Sprengel's pump lie in the simplicity of its construction and in the readiness with which it adapts itself to the collecting of the gas. It did excellent service in the hands of Graham for the extraction of gases occluded in metals, and since then has become very popular in gas-laboratories, especially in Britain. Many improvements upon the original construction have been proposed. One of these which deserves mention is to pass the mercury, before it enters the "falling" tube, through a bulb in which a good vacuum is maintained, by means of an ordinary air-pump or a second "Sprengel." (W. D.)

MERCURY was the Roman god who presided over barter, trade, and all commercial dealings. His nature is probably more intelligible and simple than that of any other Roman deity. His very name, which is connected with *merx*, *mercator*, &c., shows that he is the god of merchandise and the patron of merchants. In the native Italian states no merchants and no trade existed till the influence of the Greek colonies on the coast introduced Greek customs into the cities of the land. All the usages and terminology of trade, and all the religious ceremonies connected with it, were borrowed by the Romans from the Greeks. It was no doubt under the rule of the Tarquins, when the prosperity of the state and its intercourse with the outer world were so much increased, that merchants began to ply their trade in Rome. Doubtless the merchants practised their religious ceremonies from the first, but their god Mercurius was not officially recognized by the state till the year 495 B.C. Rome frequently suffered from scarcity of corn during the unsettled times that followed the expulsion of the Tarquins. Various religious innovations were made to propitiate the gods; in 496 the Greek worship of Demeter, Dionysus, and Persephone was established in the city (see LIBER), and in 495 the Greek god HERMES (*q.v.*) was introduced into Rome under the Italian name of Mercurius (Livy, ii. 21, 27). Preller thinks that at the same time the trade in corn was regulated by law, and a regular college of merchants was instituted. This *collegium* was under the protection of the god; their annual festival was on the Ides of May, on which day the temple of the god had been dedicated at the southern end of the *circus maximus*, near the Aventine; and the members were called *mercuriales* as well as *mercatores*. The Ides of May was chosen as the feast of Mercury, obviously because Maia was the mother of Hermes, *i.e.*, of Mercury (see MAIA); and she was worshipped along with her son by the *mercuriales* on this day. According to Preller, this religious foundation had a political object; it established on a legitimate and sure basis the trade between Rome and the Greek colonies of the coast, whereas formerly this trade had been exposed to the capricious interference of the Government officials for the year. Like all borrowed religions in Rome, it must have retained the rites and the terminology of its Greek original (Festus, p. 257). Mercury became the god, not only of the *mercatores* and of the corn trade, but of buying and selling in general; and it appears that, at least in the streets where shops were common, little chapels and images of the god were erected. There was a spring dedicated to Mercury between his temple and the *Porta Capena*; every shopman drew water from this spring on the Ides of May, and sprinkled it with a laurel twig over his head and over his goods, at the same time entreating Mercury to remove from his head and his goods the guilt of all his deceits (Ovid, *Fasti*, v. 673 *sq.*). The art of the Roman tradesman was evidently like that of an Oriental tradesman in modern times, and the word *mercurialis* was popularly used as equivalent to "cheat." In the Latin poets Mercury is often gifted with some of the manifold characters of the Greek Hermes, but this finer conception seems to have had no real existence in Roman religion.

Roman statuettes of bronze, in which Mercury is represented, like the Greek Hermes, standing holding the caduceus in the one hand and a purse in the other, are exceedingly common. The caduceus must have been introduced as a symbol of Mercury at a very early time, for it is found on Italian coins as early as the 4th century before Christ, and we learn that several were kept as sacred objects in the *adytum* of the sanctuary at Lavinium (Dion. Hal., i. 67). But its foreign origin is shown by the fact that, although it was a sign of peace, it was never borne by the *fetiales*, the old Italian heralds. The very name is derived from the Greek κηρύκειον. Preller's view (*Röm. Myth.*) that *mercuriales* and *mercatores* are the same guild is a tempting one, but its truth is very doubtful. Mommsen thinks that *mercuriales* were a purely local guild, viz., the *pagani* of the Circus valley.

MERCURY, in chemistry, is a metal (symbol Hg) which is easily distinguished from all others by its being liquid at even the lowest temperatures naturally occurring in moderate climates. To this exceptional property it owes the synonyms of *quicksilver* in English (with the Germans *quecksilber* is the only recognized name) and of *hydrargyrum* (from ὕδωρ, water, and ἄργυρος, silver) in Græco-Latin.

[1] See *Dingler's Polytechn. Journal*, 1862; an improved form by Bessel-Hagen is described in *Wiedemann's Annalen*, xii. 425, 1881.

This metal does not appear to have been known to the ancient Jews, nor is it mentioned by the earlier Greek writers. Theophrastus (about 300 B.C.) mentions it as a derivative of cinnabar. With the alchemists it was a substance of great consequence. Being ignorant of its susceptibility of freezing into a compact solid, they did not recognize it as a true metal, and yet, on the authority of Geber, they held that mercury (meaning the predominating element in this metal) enters into the composition of all metals, and is the very cause of their metallicity. When, about the beginning of the 16th century, chemistry and scientific medicine came to merge into one, this same mysterious element of "mercury" played a great part in the theories of pathology; and the metal, in the free as in certain combined states, came to be looked upon as a powerful medicinal agent, which position, on purely empirical grounds, it continues to hold to the present day.

Mercury occurs in nature chiefly in the form of a red sulphide, HgS, called cinnabar, which, as a rule, is accompanied by more or less of the reguline metal,—the latter being probably derived from the former by some secondary reaction. The most important mercury mines in Europe are those of Almaden in Spain and of Idria in Illyria; these until lately furnished the bulk of the mercury of commerce, but they are now almost eclipsed by the rich deposits of New Almaden in California. Considerable quantities of mercury are said to be produced in China and in Japan; minor deposits are being worked in the Bavarian Palatinate, in Hungary, Transylvania, Bohemia, and Peru. At Almaden the ore forms mighty veins traversing micaceous schists of the older transition period; in Illyria it is disseminated in beds of bituminous schists or compact limestone of more recent date.

Chemically speaking, the extraction of mercury from its ores is a simple matter. Metallic mercury is easily volatilized, and separated from the gangue, at temperatures far below redness, and cinnabar at a red heat is readily reduced to the metallic state by the action of iron or lime or atmospheric oxygen, the sulphur being eliminated, in the first case as sulphide of iron, in the second as sulphide and sulphate of calcium, in the third as sulphurous acid gas. To the chemical mind a close iron retort would suggest itself as the proper kind of apparatus for carrying out these operations, but this idea is acted upon only in a few small establishments,—for instance, in that of Zweibrücken in the Palatinate, where lime is used as a decomposing agent. In all the large works the decomposition of the cinnabar is effected by the direct exposure of the ore to the oxidizing flame of a furnace, and the mercury vapour, which of course gets diffused through an immense mass of combustion gases, is sought to be recovered in more or less imperfect condensers.

At Almaden this roasting distillation is effected in prismatic furnaces, which, by a second upper (brick) grating are divided into two flats, the lower one serving for the generation of a wood fire, while the upper accommodates the ore, which is introduced through an opening in the dome-shaped roof. To avoid an excessive dilution of the mercury vapour with combustion gases, part of these are led out laterally into a chimney and the rest allowed to strike up through the heap of ore. The large mass of metalliferous vapour produced passes out through a system of pipes inserted laterally into the dome and so arranged that they follow first a descending and then an ascending plane, to lead ultimately into a condensation chamber which communicates in its turn with a chimney. The pipes are formed each of a large number of elongated pear-shaped earthenware adapters (called *aludels*), which are telescoped into one another as in the case of the iodine-distillation apparatus, the joints being luted with clay. The lowest row of aludels, which lie in the line of intersection of the two inclined planes, are pierced with holes below, so that what arrives as liquid mercury there runs out into a gutter leading to a reservoir. What of mercury vapour remains uncondensed in the aludels passes into the chamber, the intention being to have it condensed there; in reality a large proportion of the mercury passes out through the chimney (and through the numerous leaks in the aludels) into the atmosphere to poison the surrounding vegetation and the workmen. Similar furnaces to the Almaden ones are used in Idria and at New Almaden; only the condensation apparatus are a little less imperfect. But in all three places the loss of metal is very considerable; at New Almaden it is said to amount to close upon 40 per cent.

The mercury obtained is purified mechanically by straining it through dense linen bags, and then sent out into commerce in leather bags, or in wrought-iron bottles provided with screw plugs, each holding about 75 ℔ avoirdupois.

According to Balling's *Metallurgische Chemie* (Bonn, 1882), the production of mercury in the years named was as follows:—

Austria, exclusive of Hungary (1880)	369 tons.
Hungary (1879)	180 ,,
Italy (1877)	55 ,,
Spain (1873)	929 ,,
United States (1875)	2054 ,,

Assuming the amount to be the same from year to year, this gives a total of 3587 tons.

The price of the metal is subject to immense fluctuations; it generally ranges from 2s. to 7s. 6d. a pound avoirdupois.

Commercial mercury, as a rule, is very pure chemically, so that it needs only to be forced through chamois leather to become fit for all ordinary applications; but the metal, having the power of dissolving most ordinary other metals, is very liable to get contaminated with these in the laboratory or workshop, and requires then to be purified. For this purpose a great many chemical methods have been proposed, which, however, all come to this, that the base admixtures are sought to be removed by treatment with nitric acid, oil of vitriol, or other agents which act preferably on the impurities. The best of these methods is that of Brühl, who shakes the metal with a solution of 5 grammes of bichromate of potash and a few cubic centimetres of sulphuric acid in one litre of water, until the red chromate of mercury, first produced, has disappeared, and its place been taken by green chromic sulphates. The supernatant liquor and chromic scum are washed away by a powerful jet of water, and the clean metal is dried and filtered through a perforated paper filter. The only really exhaustive method is redistillation out of a glass apparatus. Unfortunately the operation is difficult of execution, as mercury "bumps" badly on boiling; but this can be avoided by distilling the metal in a *perfect* vacuum. An ingenious apparatus for this purpose, in which the distilled metal itself is made to keep up the vacuum, was constructed lately by Leonhard Weber. A U-tube, the limbs of which are longer than the height of the barometer, is filled with pure mercury, and inverted, the one limb being made to dip into a vessel with pure, the other into another containing the impure, mercury. This second limb is inflated above so that the meniscus is about the middle of the bulb. This bulb is heated, and the consequence is that the metal there distils over into the first limb to add to the supply of pure metal, the impure rising up in the second by itself to maintain a constant level. Dewar has modified the apparatus so that there is no need of a supply of pure metal to start with. Absolutely pure mercury does not at all adhere to any surface which does not consist of a metal soluble in mercury. Hence the least quantity of it, when placed on a sheet of paper, forms a neatly rounded-off globule, which retains its form on being rolled about, and, when subdivided, breaks up into a number of equally perfect globules. The presence in it of the minutest trace of lead or tin causes it to "draw tails." A very impure metal may adhere even to glass, and in a glass vessel, instead of the normal convex, form an irregular flat meniscus.

Properties.—The pure metal is silver-white, and retains its strong lustre even on long exposure to ordinary air. At $-38°\cdot8$ C., *i.e.*, $-37°\cdot9$ F. (Balfour Stewart), it freezes,

with considerable contraction, into a compact mass of regular octahedra, which can be cut with a knife and be flattened under the hammer. The specific gravity of the frozen metal is 14·39; that of the liquid metal at 0° C. is 13·595 (water of 4° C. = 1). Under 760 mm. pressure it boils at 357°·3 C. (675°·1 Fahr.) (Regnault). At very low temperatures it seems to be absolutely devoid of volatility (Faraday); but from −13° C. upwards (Regnault) it exhibits an appreciable vapour tension.

The following table gives the tensions "p," in millimetres of mercury of 0° C., for a series of centigrade temperatures "t," according to Regnault:—

t = 0°	10°	20°	50°	100°	150°	200°
p = ·02	·03	·04	·11	·75	4·27	19·90
t = 250°	300°	350°	400°	450°	500°	
p = 75·75	242·1	663·2	1588	3384	6520	

According to the same authority, its average coefficient of expansion k per degree C. is as follows:—

	0–100° C.	0–200° C.	0–300° C.
	k = ·0001815	·0001841	·0001866
or	1/5510	1/5432	1/5359

Its specific heat in the liquid state is ·03332; that of the frozen metal (between −78° and −40° C.) is ·0319 (Regnault). Its electric conductivity is $\frac{1}{57}$ of that of pure silver (Matthiesen). Its conductive power for heat is greater than that of water, and is proved (by Herwig) to be perfectly constant from 40° to 160° C. Its vapour density (air of the same temperature and pressure = 1) is 6·976 (Dumas), or 100·93 for hydrogen = 1. Hence its molecular weight (H_2 = 2) is 201·86. The atomic weight, by chemical methods, was found = 200·0 (Erdmann and Marchand); hence mercury-vapour molecules consist of single atoms. Mercury does not appreciably absorb any chemically inert gas.

Mercury is in constant requisition in the laboratory. It is used for the collecting and measuring of gases, in the construction of thermometers, barometers, and manometers, for the determination of the capacity of vessels, and many other purposes. In medicine it serves for the preparation of mercurial ointment and of "hydrargyrum cum creta" (the chief component of "blue pills"); both are obtained by diligently triturating the metal with certain proportions of grease and chalk respectively until it is "deadened," *i.e.*, subdivided into invisibly small globules (see below).

Alloys.—Mercury readily unites directly with all metals (except iron and platinum) into what are called amalgams. In some cases the union takes place with considerable evolution of heat and large modification of the mean properties of the components. Thus, for instance, sodium when rubbed up with mercury unites with it with deflagration and formation of an alloy which, if it contains more than 2 per cent. of sodium, is hard and brittle, although sodium is as soft as wax and mercury a liquid. Liquid amalgams of gold and silver are employed for gilding and silvering objects of copper, bronze, or other base metal. The amalgam is spread out on the surface of the object by means of a brush, and the mercury then driven off by the application of heat, when a polishable, firmly adhering film of the noble metal remains. Copper amalgam containing from 25 to 33 per cent. of the solid metal, when worked in a mortar at 100° C., becomes highly plastic, but on standing in the cold for ten or twelve hours becomes hard and crystalline. Hence it is used for the stuffing of teeth. A certain amalgam of cadmium is similarly employed.

Oxides.—There are two oxides of mercury, namely, an oxide, Hg_2O, called mercurous, and another, HgO, called mercuric oxide. The latter can be produced directly by keeping the metal for a long time in air at a temperature somewhat below its boiling point, when the oxide is gradually formed as a red powdery solid. This solid has long been known as "red precipitate," or as *mercurius præcipitatus per se.* Priestley made the important discovery that the "precipitate" when heated to dull redness is reduced to metal, with evolution of what has since been known as oxygen gas; but it was reserved for Lavoisier to correctly interpret this experiment, and thus to establish our present views on the constitution of atmospheric air. The oxide is easily prepared by heating any nitrate of the metal as long as nitrous fumes are seen to go off (when it remains as a scaly mass, black when hot, red after cooling), or else by precipitating the solution of a mercuric salt with excess of caustic potash or soda, when it comes down as an amorphous yellow precipitate, which is free of combined water. Mercurous oxide, a black solid, can be obtained only indirectly, by the decomposition of mercurous salts with fixed caustic alkalies. Both oxides are insoluble in water, but dissolve in certain, and combine with all, aqueous acids with formation of mercury salts and elimination of water. Thus, for instance,

$$Hg_2O + 2HNO_3 = H_2O + \underset{\text{Mercurous nitrate}}{Hg_2(NO_3)_2},$$

$$HgO + 2HNO_3 = H_2O + \underset{\text{Mercuric nitrate.}}{Hg(NO_3)_2}.$$

The Nitrates.—When metallic mercury is set aside with its own weight of nitric acid of 1·2 specific gravity, at ordinary temperatures, the normal mercurous salt $Hg_2(NO_3)_2$ is gradually produced, and after a day or two is found to have separated out in colourless crystals. These are soluble (somewhat sparingly) in water acidulated with nitric acid, but are decomposed by the action of pure water, with formation of difficultly soluble basic salts. When this salt (or the metal itself) is treated with excess of nitric acid it is oxidized into mercuric nitrate $Hg(NO_3)_2$, a white crystalline salt, readily soluble in water without decomposition.

The Sulphates.—Cold aqueous sulphuric acid does not act upon mercury, but the hot concentrated acid converts it first into mercurous and then into mercuric sulphate, with evolution of sulphurous acid.

$$Hg_2 + 2H_2SO_4 = 2H_2O + SO_2 + Hg_2SO_4,$$

$$Hg_2SO_4 + 2H_2SO_4 = 2H_2O + SO_2 + 2HgSO_4.$$

Both salts form white crystalline magmas. The mercurous salt is difficultly soluble in water, and consequently producible by precipitation of the nitrate with sulphuric acid. The mercuric salt, when treated with water, is decomposed with formation of a yellow insoluble basic salt, which has long been known as *turpethum minerale.* Its composition is $SO_3 . 3HgO$ when produced by excess of hot water. Mercuric sulphate is of importance chiefly as forming the basis for the manufacture of the two chlorides.

The Chlorides.—These are both extensively used medicinal agents. The mercuric salt, $HgCl_2$, known in medicine as corrosive sublimate, is prepared by mixing the sulphate intimately with common salt, and subjecting the mixture to sublimation, a little binoxide of manganese being added to oxidize the mercurous salt, which is generally present as an impurity. The process is conducted in a glass flask buried in a hot sand-bath. When the decomposition is accomplished, the sand is removed from the upper half of the flask and the temperature raised so that the chloride $HgCl_2$ produced sublimes up and condenses in the upper part as a "sublimate." The salt, as thus produced, forms compact crystalline crusts, which, when heated, melt into a limpid liquid before volatilizing. It is soluble in water, 100 parts of which at 10°, 20°, 100° dissolve 6·57, 7·39, 54 parts of salt. Corrosive sublimate dissolves in 3 parts of alcohol and in 4 parts of ether. This salt, on account of its solubility in water, is a deadly poison. Mercurous chloride, Hg_2Cl_2, better known as "calomel" (from καλός, fair, and μέλας, black, because it becomes dead-black when treated with ammonia, mercuric chloride yielding a white product), is prepared by mixing corrosive sublimate with the proper proportion of metallic mercury ($HgCl_2$: Hg) or mercuric sulphate with salt and mercury in the proportions of $HgSO_4$: Hg : 2NaCl, and subjecting the mixture to sublimation in glass flasks. The salt Hg_2Cl_2 is thus obtained in the form of white, opaque, crystalline crusts, which, when heated, volatilize, without previously melting, into a mixture of $HgCl_2$ and Hg vapour, which, on cooling, recombine into calomel. For medicinal purposes the sublimate is reduced to an impalpable powder, washed with water to remove any corrosive sublimate that may be present, and dried. Being insoluble in water, it acts far less violently on the organism than mercuric chloride does. Its action, no doubt, is due to its very gradual conversion in the stomach into mercury and corrosive sublimate. Finely divided calomel can be produced, without trouble, by the precipitation of a solution of mercurous nitrate with hydrochloric acid or common salt; but this preparation is liable to be contaminated with mercurous nitrate, and, even when pure, has been found to act far more violently than ordinary calomel does. Hence its use is not tolerated by the pharmacopœias. According to Wöhler a mercurous chloride, more nearly equivalent to the sublimed article, is producible by heating corrosive sublimate solution with sulphurous acid—

$$2HgCl_2 + H_2SO_3 + H_2O = H_2SO_4 + 2HCl + Hg_2Cl_2.$$

The writer is unable to say whether Wöhler's calomel has ever found its way anywhere into medicinal practice.

The Iodides.—The mercuric salt HgI_2 is produced in two ways, viz., first by mixing the two elementary components intimately and subjecting the mixture to sublimation, and secondly by precipitating corrosive sublimate solution with its exact equivalent of iodide of potassium. In the first case the salt is obtained in yellow crystals, which, on the slightest touch with a solid body, assume and then permanently retain a rich scarlet colour. The precipitation process at once yields the scarlet salt. The salt is insoluble in water, but soluble in alcohol and in iodide of potassium solution. The mercurous salt Hg_2I_2 is obtained by precipitating mercurous nitrate with iodide of potassium as a dirty-green powder insoluble in water. Both iodides are used medicinally.

The Sulphides.—Mercurous sulphide, Hg_2S, does not seem to exist. The mercuric salt, HgS, exists in two modifications, of which one is amorphous and has a black colour, while the other is crystalline and red. The black one is obtained by precipitation of solutions of mercuric salts with excess of sulphuretted hydrogen, or by direct synthesis. The right proportions of mercury and flowers of sulphur are rubbed together in a mortar until the whole is converted into a jet-black uniform powder. This preparation (the *æthiops mineralis* of the pharmaceutist), however, is apt to be contaminated with uncombined sulphur and mercury. Application of a gentle heat causes exhaustive combination. The red sulphide, HgS, occurs in nature as cinnabar, and can be produced artificially from the black. The artificial preparation, known as vermilion, is highly valued as the most brilliant, stable, and innocuous of all mineral red pigments. Vermilion can be produced from the black sulphide in two ways, viz., first by sublimation, and secondly by treatment of it with fixed alkaline sulphide solution. According to Brunner, 100 parts of mercury are mixed intimately with 38 parts of flowers of sulphur, and the æthiops is digested, with constant agitation, in a solution of 25 parts of potash in 150 parts of water at 45° C. (the water lost by evaporation being constantly replaced), until the preparation has come up to its maximum of fire and brilliancy, which takes a good many hours. Purely sublimed vermilion has a comparatively dull colour, and must be manipulated with alkaline sulphide solution to give it the necessary fire. The action of the alkaline sulphide consists probably in this, that it dissolves successive instalments of the amorphous preparation and redeposits them in the crystalline form.

Mercuric Derivatives of Ammonia.—(1) Recently precipitated oxide HgO is digested, cold, in carbonic-acid-free ammonia, and the mixture allowed to stand for a few days. The liquor is then decanted off, and the precipitate washed with alcohol and then with ether, and dried over sulphuric acid. The product is a yellow solid base ("Millon's base") of the composition

$$N_2H_6 + 4HgO + H_2O = N_2Hg_4O \,.\, 2H_2O + 2H_2O \,.$$

It is insoluble in alcohol and in ether, and requires 13,000 parts of cold water for its solution. It readily unites with all acids, forming salts, which, as a rule, are insoluble in water. Hence all ordinary salt solutions, when shaken with the base, are decomposed with elimination of the base of the salt. Thus, for instance, even such salts as alkaline nitrates, chlorides, or sulphates are decomposed with formation of solutions of caustic alkali.

(2) A body $N_2Hg_4I_2 + 2H_2O$, *i.e.*, of the composition of the iodide corresponding to the oxide in (1), is produced as a brown precipitate when ammonia or an ammonia salt is added to a solution of mercuric iodide in iodide of potassium mixed with large excess of caustic potash or soda ("Nessler's reagent"). In very dilute solutions of ammonia Nessler's reagent produces only a brown or yellow coloration, which, however, is so intense that $\frac{1}{20000000}$th of ammonia in about 50 cubic centimetres of liquid becomes clearly visible.

(3) The chloride $NH_2Hg \,.\, Cl$ of the "ammonium" NH_2Hg is produced as an insoluble white precipitate when ammonia is added to a solution of corrosive sublimate. This substance is known in medicine as infusible white precipitate, in contradistinction to (4).

(4) The fusible white precipitate was at one time supposed to be identical with (3), and is obtained by boiling it with sal-ammoniac solution. Its composition is $NH_2HgCl + NH_4Cl = N_2H_6 \,.\, Hg \,.\, Cl_2$.

Analysis.—Any ordinary solid mercury compound, when heated in a sublimation tube with carbonate of soda, yields a sublimate of metallic mercury, which, if necessary, needs only to be scraped together with a wooden spill to unite into visible globules. From any mercury-salt solution the metal is precipitated by digestion with a piece of bright copper-foil. The precipitated mercury forms a coating on the copper, which becomes silvery on being rubbed with blotting paper. When the quicksilvered copper is heated in a sublimation tube, it reassumes its red colour with formation of a sublimate of mercury.

Solutions of mercurous salts with hydrochloric acid give a white precipitate of calomel, which, after filtration, is easily identified by its becoming jet-black on treatment with ammonia. From mercuric solutions hydrochloric acid precipitates nothing; but stannous chloride, in its twofold capacity as a chloride and a reducing agent, yields a precipitate of calomel. On addition of an excess of reagent the precipitate becomes grey through conversion into finely divided quicksilver. Sulphuretted hydrogen, when added very gradually to an acid mercuric solution, gives at first an almost white precipitate, which, on addition of more and more reagent, assumes successively a yellow, orange, and at last jet-black colour. The black precipitate is HgS, which is identified by its great heaviness, and by its being insoluble in boiling nitric and in boiling hydrochloric acid. A mixture of the two (aqua regia) dissolves it as chloride. (W. D.)

Therapeutics of Mercury.

The use of mercury as a therapeutic agent is of comparatively recent date. To the Greeks and Romans its value was unknown, and the Arabian physicians only used it for skin affections. It was not till the middle of the 16th century that the special properties of mercury were fully appreciated, but since that time the metal has continued to hold a high though fluctuating value as a medicine. At first the metal in a finely divided state or in vapour was used; but very soon its various compounds were found to be endowed with powers even greater than those of the metal itself, and with the discovery of new compounds the number of mercurial medicines has largely increased.

The preparations now in use may be thus classified. (1) Of the preparations containing metallic mercury the chief members are blue pill (pilula hydrargyri), grey powder (hydrargyrum cum creta), and blue ointment (unguentum hydrargyri). The first consists of mercury, liquorice root, and confection of roses, the second of mercury and chalk, the third of mercury, suet, and lard. The power of the three preparations seems to depend on the fine state of subdivision of the mercury they contain; mercury in its ordinary liquid state seems devoid of medicinal properties. It is thought by some that the fine subdivision of the metal leads to the formation of a little oxide, and that the efficacy of the preparations in part depends on this. (2) Three oxides of mercury are employed in medicine,—the red, from which is made red precipitate ointment (unguentum hydrargyri oxydi rubri), the yellow, an allotropic form of the red, and the black oxide. The yellow and black oxides suspended in lime water form respectively yellow and black wash (lotio flava and lotio nigra). (3) The chlorides of mercury form a very important group: calomel (hydrargyri subchloridum) is a white heavy powder; corrosive sublimate (hydrargyri perchloridum) is a heavy crystalline substance. (4) Two iodides are used medicinally; they are known from their colour as the green and red iodides. (5) Nitrate of mercury enters into the composition of a powerful caustic known as the acid nitrate of mercury. It is also the active principle of citrine ointment (unguentum hydrargyri nitratis). (6) In this class only ammoniated mercury and its ointment commonly known as white precipitate ointment, are contained. Of the many compounds not included in the above classification the oleate and albuminate are the most important.

Mercurial preparations are largely employed as external applications. Several of them are potent agents for the destruction of the lower forms of animal life, and hence are employed to destroy parasites having their habitat in skin, hair, and clothing. The white and red precipitate ointments are specially effective in the destruction of pediculi, and blue ointment is occasionally used for the same purpose. Corrosive sublimate is, however, the most energetic of the mercurial parasiticides, and recent observations seem to show that it is superior to almost all other substances as a germ destroyer. It is sometimes used to get rid of ringworm. It should be remembered that corrosive sublimate is a powerful irritant to the skin, and also an active poison.

Acid nitrate of mercury is a caustic, and by it warts and small growths are sometimes removed; it is also one of the caustics occasionally applied to prevent the spread of lupus.

In skin diseases mercurial preparations are largely used, especially in some forms of eczema. A few grains of the red oxide or of ammoniated mercury in an ounce of zinc ointment are often found of great service in this ailment; citrine ointment is also useful.

Calomel ointment is not irritating, but rather tends to soothe. It is therefore sometimes applied to irritable rashes; in pruritus ani it is of special value. Mercurial preparations are not usually found of benefit in scaly eruptions. In acne a weak solution of corrosive sublimate is often most effective.

Preparations of mercury are often used to heal ulcers, especially those of syphilitic origin. Black wash is one of the commonest applications for this purpose. The red oxide ointment is at times employed to stimulate indolent ulcers, and it is capable of removing exuberant granulations (proud flesh), which sometimes retard the healing of wounds.

Mercury is largely used externally to promote the absorption of inflammatory products, especially in the neighbourhood of joints. The blue ointment is frequently employed for this purpose, more rarely a plaster containing mercury or a mercurial liniment. For effecting the absorption of goitre (Derbyshire neck) the ointment of the red iodide is often relied on, especially in India, where it is customary to expose the patient's neck to the sun after rubbing it with the ointment. In enlargements of the liver and spleen the application of mercurial ointment sometimes seems to promote reduction in size.

Taken internally in continued doses, mercury produces a peculiar effect known as salivation. First a metallic taste is experienced; this is followed by soreness of the gums, an undue flow of saliva, and fœtor of the breath. Further administration of the drug may increase greatly the salivary flow, and also lead to swelling of the tongue, ulceration of the mouth, and even disease of the jaw-bone. At the same time the blood becomes impoverished, and feverishness with loss of flesh occurs. A single large dose—rarely too a single small dose—may produce some of the above symptoms. They may also follow the inhalation of the metal or its compounds, or their absorption through the skin. The long-continued inhalation of the vapour of mercury acts likewise on the nervous system, causing a peculiar kind of trembling. Mercurial tremor is sometimes seen in looking-glass makers, often in those who work in quicksilver mines.

Internally mercury is chiefly given for two purposes—(1) to check inflammation and cause the absorption of the products it gives rise to, and (2) to antagonize the syphilitic virus and remove the evils it causes. Some years ago the belief in the power of mercury to control inflammation was almost universal, and it was largely administered in almost all inflammatory affections, but of late it has been much less used, both because it seems doubtful whether it has really the power it was once supposed to have and because of the possibility of evil results from its continued use. In peritonitis and iritis it is still often employed, small doses of calomel being given. Not unfrequently too it is administered in pericarditis and hepatitis, but in pneumonia, pleurisy, and most other inflammatory affections its use is now discarded by many physicians. As an antidote to the syphilitic poison it is still held in high esteem, though opinions vary much as to the extent of its power. There can be little doubt that, given in an early stage of the disorder, it minimizes the secondary symptoms; but it cannot be relied on to prevent their occurrence. It aids in removing the secondary symptoms, and tends to the avoidance of tertiary manifestations, which nevertheless sometimes occur even when mercury has been freely given. The custom of giving mercury till profuse salivation is established has long been abandoned; the aim now is so to give it as to prevent salivation occurring; for this purpose blue pill, calomel, and corrosive sublimate are given in very small doses, but if the gums become tender the dose is decreased or the administration stopped.

Mercurial treatment is sometimes carried out by rubbing the blue ointment into the skin, sometimes by exposing the patient to the fumes of calomel; syphilitic eruptions are often treated by such fumigation. More rarely mercury is introduced by injecting the albuminate or some other preparation under the skin or by means of suppositories. In children grey powder is generally used when mercurial treatment is required. Children bear mercury well.

Blue pill, calomel, and grey powder are often used as purgatives, and a power of promoting the secretion of bile is attributed to them. Experimentally it has not been proved that they stimulate the liver functions, but there is good reason for believing that they promote the expulsion of bile from the body. Grey powder is especially valued as a mild and efficient aperient for children, and is often given in the early stage of diarrhœa to expel the irritating contents of the bowel.

The use of calomel in tropical dysentery, once very prevalent, has within the last few years been abandoned. (D. J. L.)

MERGANSER, a word originating with Gesner (*Hist. Animalium*, iii. p. 129) in 1555, and for a long while used in English as the general name for a group of fish-eating Ducks possessing great diving powers, and forming the genus *Mergus* of Linnæus, now regarded by ornithologists as a Subfamily, *Merginæ*, of the Family *Anatidæ*. The Mergansers have a long, narrow bill, with a small but evident hook at the tip, and the edges of both mandibles beset by numerous horny denticulations, whence in English the name of "Saw-bill" is frequently applied to them. Otherwise their structure does not much depart from the Anatine or Fuliguline type. All the species bear a more or less developed crest or tuft on the head. Three of them, *Mergus merganser* or *castor*, *M. serrator*, and *M. albellus*, are found over the northern parts of the Old World, and of these the first two also inhabit North America, which has besides a fourth species, *M. cucullatus*, said to have occasionally visited Britain. *M. merganser*, commonly known as the Goosander, is the largest species, being nearly as big as the smaller Geese, and the adult male in breeding-attire is a very beautiful bird, conspicuous with his dark glossy-green head, rich salmon-coloured breast, and the upper part of the body and wings black and white. This full plumage is not assumed till the second year, and in the meantime, as well as in the post-nuptial dress, the male much resembles the female, having, like her, a reddish-brown head, the upper parts greyish-brown, and the lower dull white. In this condition the bird is often known as the "Dun Diver." This species breeds abundantly in many parts of Scandinavia, Russia, Siberia, and North America, and of late years has been found to do so in Scotland, usually making its nest in the stump of a hollow tree or under a slab of rock. *M. serrator*, commonly called the Red-breasted Merganser, is a somewhat smaller bird; and, while the fully-dressed male wants the delicate hue of the lower parts, he has a gorget of rufous mottled with black, below which is a patch of white feathers, broadly edged with black. The male at other times and the female always much resemble the preceding. It is more numerous than the Goosander, with a somewhat more southern range, and is not so particular in selecting a sheltered site for its nest. Both these species have the bill and feet of a bright reddish-orange, while *M. albellus*, known as the Smew, has these parts of a lead colour, and the breeding plumage of the adult male is white, with quaint crescentic markings of black, and the flanks most beautifully vermiculated—the female and male in undress having a general resemblance to the other two already described—but the Smew is very much smaller in size, and, so far as is known, it invariably makes its nest in a hollow tree, as ascertained first by Wolley (*Ibis*, 1859, pp. 69 *et seq.*). This last habit is shared by *M. cucullatus*, the Hooded Merganser of North America, in size intermediate between *M. albellus* and *M. serrator*, the male of which is easily recognizable by his broad semicircular crest, bearing a fan-shaped patch of white, and his elongated subscapulars of white edged with black. The conformation of the trachea in the male of *M. merganser*, *M. serrator*, and *M. cucullatus* is very like that of the Ducks of the genus *Clangula*, but *M. albellus* has a less exaggerated development more resembling that of the ordinary *Fuligula*.[1] From the southern hemisphere two species of *Mergus* have been described, *M. octosetaceus* or *brasilianus*, Vieillot (*N. Dict. d'Hist. Naturelle*, ed. 2, xiv. p. 222; *Gal. des Oiseaux*,

[1] Hybrids between, as is presumed, *M. albellus* and *Clangula glaucion*, the common Golden-eye, have been described and figured (Eimbeck, *Isis*, 1831, 300, tab. iii.; Brehm, *Naturgesch. aller Vög. Deutschlands*, p. 930; Naumann, *Vög. Deutschlands*, xii. p. 194, frontispiece; Kjærbölling, *Jour. für Ornithologie*, 1853, Extraheft, p. 29, *Naumannia*, 1853, p. 327, *Ornithol. Danica*, tab. lv., suppl. tab. 29) under the names of *Mergus anatarius*, *Clangula angustirostris*, and *Anas (Clangula) mergoides*, as though they were a distinct species; but the remarks of M. de Selys-Longchamps (*Bull. Ac. Sc. Bruxelles*, 1845, pt. ii. p. 354, and 1856, pt. ii. p. 21) leave little room for doubt as to their origin, which, when the cryptogamic habit and common range of their putative parents, the former unknown to the author last-named, is considered, will seem to be still more likely.

tom. ii. p. 209, pl. 283), inhabiting South America, of which but few specimens have been obtained, having some general resemblance to *M. serrator*, but much more darkly coloured, and *M. australis*, Hombron and Jacquemont (*Ann. Sc. Nat. Zoologie*, ser. 2, xvi. p. 320; *Voy. au Pol Sud, Oiseaux*, pl. 31, fig. 2), as yet known only by the unique example in the Paris Museum procured by the French Antarctic expedition in the Auckland Islands. This last species may perhaps be found to visit New Zealand, and should certainly be looked for there.

Often associated with the Mergansers is the genus *Merganetta*, the so-called Torrent-Ducks of South America, of which three species are said to exist; but they possess spiny tails and have their wings armed with a spur. Whether they should be referred to the *Merginæ* or the *Erismaturinæ*—the Spiny-tailed Ducks proper—is a question that further investigation must decide. (A. N.)

MERGUI, a district of British Burmah, between 9° 58′ and 13° 24′ N. lat. It forms the southernmost district of the Tenasserim division, and is bounded on the N. by Tavoy, E. and S. by Siam, and W. by the Bay of Bengal, with an area of 7810 square miles. Two principal ranges cross Mergui from north to south, running almost parallel to each other for a considerable distance, with the Tenasserim river winding between them till it turns south and flows through a narrow rocky gorge in the westernmost range to the sea. Amongst these mountain ranges and their subsidiary spurs are several fertile plains, densely clothed with luxuriant vegetation. Indeed, the whole district, from the water's edge to the loftiest mountain on the eastern boundary, may be regarded as almost unbroken forest, only 73 square miles being under cultivation. The timber trees found towards the interior, and on the higher elevations, are of great size and beauty, the most valuable being teak, *then-gan* (*Hopea odorata*), *ka-gnyeng* (*Dipterocarpus tuberculatus*), &c. The coast-line of the district, studded with an archipelago of two hundred and seven islands, is much broken, and for several miles inland is very little raised above sea-level, and is drained by numerous muddy tidal creeks. Southwards of Mergui town it consists chiefly of low mangrove swamps alternating with small fertile rice plains. After passing the mangrove limits, the ground to the east gradually rises till it becomes mountainous, even to the banks of the rivers, and finally culminates in the grand natural barrier dividing British Burmah from Assam. The four principal rivers are the Tenasserim, Le-gnya, Pakchan, and Palouk, the first three being navigable for a considerable distance of their course. Coal is found in the district on the banks of the Tenasserim and its tributaries. Gold, copper, iron, and manganese are also found in various parts of the district.

From the notices of early travellers it appears that Mergui, when under Siamese rule, before it passed to the Burmese, was a rich and densely peopled country. On its occupation by the British in 1824–25 it was found to be almost depopulated—the result of border warfare and of the cruelties exercised by the Burmese conquerors. At that time the entire inhabitants only numbered 10,000; in 1876 they had increased to 51,846 (26,767 males and 25,079 females). Classified according to religion, there were—Buddhists, 48,750; Mohammedans, 2533; Hindus, 353; Christians and others, 210. The district contains only one town (Mergui) with more than 5000 inhabitants. Only 73 square miles of the district area were under cultivation in 1876, but this area is steadily though slowly increasing. The principal manufactures are sugar-boiling and tin-smelting. Mergui carries on a flourishing trade with Rangoon, Bassein, and the Straits Settlements. The chief exports consist of rice, rattans, torches, dried fish, areca-nuts, sesamum seeds, molasses, sea-slugs, edible birds' nests, and tin. The staple imports are piece goods, tobacco, cotton, earthenware, tea, and sugar. The imperial revenue in 1876 amounted to £18,208. The climate is remarkably healthy, the heat due to its tropical situation being moderated by land and sea breezes. The rainfall in 1876 amounted to 165¼ inches. The prevalent diseases are simple and remittent fevers, bronchitis, rheumatism, and small-pox.

MERGUI, chief town of the above district, is situated on an island at the mouth of the Tenasserim river. The population (10,731 in 1876–77) consists of many races—Talaings, Burmese, Malays, Bengalis, Madrasis, Siamese, and Chinese. Considerable trade is carried on with other Burmese ports and the Straits Settlements. The harbour admits vessels drawing 18 feet of water.

MÉRIDA, a city of 7390 inhabitants (1877), in the province of Badajoz, Spain, lies about 36 miles by rail eastward from Badajoz, on the Madrid and Badajoz line, on a small eminence on the right bank of the Guadiana. It is connected by a branch line of rail with Llerena on the south-east. The population is mostly agricultural. The city owes its interest entirely to its Roman remains, which are numerous and extensive. Of these one of the most important is the bridge of 81 arches of granite, erected by Trajan; it is 2575 feet long, 26 feet broad, and 33 feet above the bed of the river; it was unfortunately seriously injured during the siege of Badajoz in 1812. Of the colossal wall that formerly surrounded the town all that remains is a fine fragment, built of dressed stone, on the spot formerly occupied by the castellum, and where the provisor of the order of Santiago afterwards had his residence (El Conventual). In the town are some relics of temples of Diana, Mars, Fortuna, Jupiter, and others; and the Arco de Santiago, 44 feet high, also dates from Trajan's time; it has unfortunately been stripped of its marble casing. Of the aqueduct from the laguna of Albuera thirty-seven enormous piers are still standing, with ten arches in three tiers built of brick and granite. To the east of the city is the circus, measuring some 1356 by 335 feet; the eight rows of seats still remain. Further eastward is the almost perfect theatre, and near it are the remains of the amphitheatre, or, as some prefer to call it, naumachia (Baño de los Romanos).

Augusta Emerita was built in 25 B.C. by the emeriti of the fifth and tenth legions who had served in the Cantabrian war under Augustus. It rose to great splendour and importance as the capital of Lusitania. During the Gothic period it became an episcopal see, and several provincial councils known to history were held there. It was taken by Músa in 711, and reconquered by Alphonso in 1228.

MERIDA, the capital of the Mexican state of Yucatan, stands in a great plain in the north of the peninsula, on a surface of limestone rock, about 25 miles from the port of Progreso on the Gulf of Mexico, with which it is connected by a railway opened in 1880. It is a well-built city, with broad streets and squares; and the flat-roofed stone houses, after the style introduced by the Spaniards, give a Moorish colour to the general view. Besides the cathedral, an imposing edifice of the 16th century, the bishop's palace, and the Government house (all of which are situated in the principal square), the most notable building is the Franciscan monastery (1547–1600), which once harboured within its high and turreted walls no fewer than two thousand friars, but has been allowed to fall into complete decay since their expulsion in 1820. For a long time Merida has had the reputation of being one of the principal seats of culture in Mexico; and it possesses, besides the ecclesiastical seminary, schools of law, medicine, and pharmacy, a literary institute, a public library, a theatre, and a considerable number of periodical publications. Commercially it has shared in the prosperity which Yucatan in recent years owes to the development of the Sisal hemp trade; and its manufactures embrace cotton goods, cigars, sugar, and rum. The population, estimated about 1840 as 25,000, was found in 1871 to number 33,025. The Mayas still form numerically the strongest element. Previous to the Spanish conquest the site of Merida was occupied by the Maya town of Tehoo, which contained so great a number of artificial stone-mounds that the new-comers had abundant material for all their buildings. The foundation of the

city dates from 1542, and it was made a bishopric in 1561. Compare Stephen's *Yucatán.*

MERIDEN, a city of the United States, in New Haven county, Connecticut, 18 miles from New Haven by rail. It is a busy manufacturing town; the population has increased from 3559 in 1850 to 7426, 10,495, and 18,340 in 1860, 1870, and 1880. The Britannia Company alone employs upwards of 1000 hands, and sends out every year nearly $3,000,000 worth of Britannia metal and electro-plated goods; and tin-ware, cutlery, brass-work, flint glass, guns, and woollen goods are also manufactured in the town. The State reform school had 307 inmates in 1880. A fortified tavern erected by Belcher in 1660 on the road between Boston and New Haven was the nucleus of Meriden; but the place was not incorporated as a town till 1866, and became a city in 1867.

MÉRIMÉE, PROSPER (1803–1870), novelist, archæologist, essayist, and in all these capacities one of the greatest masters of French style during the century, was born at Paris on September 28, 1803, and died at Cannes on the 23d of the same month sixty-seven years later, having lived just long enough to know that ruin was threatening France. Not many details have been published in reference to his family, but his father seems to have been a man of position and competence. Mérimée had English blood in his veins on the mother's side, and was always considered, at least in France, to look and behave more like an Englishman than a Frenchman. He was educated for the bar, but entered the public service instead. A young man at the time of the romantic movement, he felt its influence strongly, though his peculiar temperament prevented him from joining any of the côteries of the period. This temperament was indeed exhibited by the very form and nature of the works in which he showed the influence of romanticism. Nothing was more prominent among the romantics than the fancy, as Mérimée himself puts it, for "local colour," the more unfamiliar the better. Mérimée exhibited this in an unusual way. In 1825 he published what purported to be the dramatic works of a Spanish lady, Clara Gazul, with a preface stating circumstantially how the supposed translator, one Joseph L'Estrange, had met the gifted poetess at Gibraltar. This was followed by a still more audacious and still more successful *supercherie.* In 1827 appeared a small book entitled *La Guzla* (the anagram of Gazul), and giving itself out as translated from the Illyrian of a certain Hyacinthe Maglanovich. This book, which has greater formal merit than *Clara Gazul*, is said to have taken in Sir John Bowring, a competent Slav scholar, the Russian poet Poushkin, and some German authorities, although not only had it no original, but, as Mérimée declares, a few words of Illyrian and a book or two of travels and topography were the author's only materials. In the next year appeared a short dramatic romance, *La Jacquerie*, in which all Mérimée's characteristics are visible—his extraordinary faculty of local and historical colour, his command of language, his grim irony, and a certain predilection for tragic and terrible subjects which was one of his numerous points of contact with the men of the Renaissance. This in its turn was followed by a still better piece, the *Chronique de Charles IX.*, which stands towards the 16th century much as the *Jacquerie* does towards the Middle Ages. All these works were to a certain extent second-hand, being either directly imitated or prompted by a course of reading on a particular subject. But they exhibited all the future literary qualities of the author save the two chiefest, his wonderfully severe and almost classical style, and his equally classical solidity and statuesqueness of construction. For the latter there was not much opportunity in their subjects, and the former required a certain maturity and self-discipline which Mérimée had not yet given to himself. These were, however, displayed fully in the famous Corsican story of *Colomba*, published in the momentous year 1830. This, all things considered, is perhaps Mérimée's best tale.

He had already obtained a considerable position in the civil service, and after the revolution of July he was *chef de cabinet* to two different ministers. He was then appointed to the more congenial post of inspector of historical monuments. Mérimée was a born archæologist, combining linguistic faculty of a very unusual kind with the accurate scholarship which does not always accompany it, with remarkable historical appreciation, and with a sincere love for the arts of design and construction, in the former of which he had some practical skill. In his official capacity he published numerous reports, some of which, with other similar pieces, have been republished in his works. He also devoted himself to history proper during the latter years of the July monarchy, and published numerous essays and works of no great length, chiefly on Spanish, Russian, and ancient Roman history. He did not, however, neglect novel writing during this period, and numerous short tales, almost without exception masterpieces, appeared, chiefly in the *Revue de Paris.* He travelled a good deal, both for his own amusement and on official errands; and in one of his journeys to Spain, about the middle of Louis Philippe's reign, he made an acquaintance destined to influence his future life not a little—that of Madame de Montijo, mother of the future empress Eugenie. Mérimée, though in manner and language the most cynical of men, was a devoted friend, and shortly before the accession of Napoleon III. he had occasion to show this. His friend Libri was accused of having stolen valuable manuscripts and books from French libraries, and Mérimée took his part so warmly that he was actually sentenced to and underwent fine and imprisonment. He had been elected of the Academy in 1844, and also of the Academy of Inscriptions, of which he was a prominent member. Between 1840 and 1850 he wrote more tales, the chief of which were *Arsène Guillot* and *Carmen.*

The empire made a considerable difference in Mérimée's life. He was not a very ardent politician, but all his sympathies were against democracy, and he had therefore no reason to object to the Bonapartist rule, especially as his habitual cynicism and his irreligious prejudices made legitimism distasteful to him. But the marriage of Napoleon III. with the daughter of Madame de Montijo at once enlisted what was always the strongest of Mérimée's sympathies—the sympathy of personal friendship—on the emperor's side. He was made a senator, and continued to exercise his archæological functions; but his most important rôle was that of a constant and valued private friend of both the "master and mistress of the house," as he calls the emperor and empress in his letters. He was occasionally charged with a kind of irregular diplomacy, and once, in the matter of the emperor's *Cæsar*, he had to pay the penalty frequently exacted from great men of letters by their political or social superiors who are ambitious of literary reputation. But for the most part he was strictly the "ami de la maison." At the Tuileries, at Compiègne, at Biarritz, he was a constant though not always a very willing guest, and his influence over the empress was very considerable and was fearlessly exerted, though he used to call himself, in imitation of Scarron, "le bouffon de sa majesté." His occupations during the last twenty years of his life were numerous and important, though rather nondescript. He found, however, time for not a few more tales, of which more will be said presently, and for two correspondences, which are not the least of his literary achievements, while they have an extraordinary interest of matter. One of these consists

of the letters which have been published as *Lettres à une Inconnue*, the other of the letters addressed to Sir Antonio Panizzi, the late librarian of the British Museum. Various, though idle and rather impertinent, conjectures have been made as to the identity of the *inconnue* just mentioned. It is sufficient to say that the acquaintance extended over many years, that it partook at one time of the character of love, at another of that of simple friendship, and that Mérimée is exhibited under the most surprisingly diverse lights, most of them more or less amiable, and all interesting. The correspondence with Panizzi has somewhat less personal interest. Mérimée made the acquaintance originally by a suggestion that his correspondent should buy for the Museum some MSS. which were in the possession of Stendhal's sister, and for some years it was chiefly confined to correspondence. But Mérimée often visited England, where he had many friends (among whom the late Mr Ellice of Glengarry was the chief), and certain similarities of taste drew him closer to Panizzi personally, while during part of the empire the two served as the channel for a kind of unofficial diplomacy between the emperor and certain English statesmen. These letters are full of shrewd *aperçus* on the state of Europe at different times. Both series abound in gossip, in amusing anecdotes, in sharp literary criticism, while both contain evidences of a cynical and Rabelaisian or Swiftian humour which was very strong in Mérimée. This characteristic is said to be so prominent in a correspondence with another friend, which now lies in the library at Avignon, that there is but little chance of its ever being printed. A fourth collection of letters, of much inferior extent and interest, has been printed by M. Blaze de Bury under the title of *Lettres à une autre Inconnue*. In the latter years of his life Mérimée suffered very much from ill health. It was necessary for him to pass all his winters at Cannes, where his constant companions were two aged English ladies, friends of his mother. The terrible year found him completely broken in health, and anticipating the worst for France. He lived long enough to see his fears realized, and to express his grief in some last letters, and he died on September 23, 1870.

Mérimée's character (which has been unwarrantably slandered by those to whom political differences or his sarcastic intolerance of "pose" in literature made him obnoxious) was a peculiar and in some respects an unfortunate one, but by no means unintelligible, and perhaps in a minor degree not uncommon. Partly by temperament, partly it is said owing to some childish experience, when he discovered that he had been duped and determined never to be so again, not least owing to the example of Beyle, who was a friend of his family, and of whom he saw much, Mérimée appears at a comparatively early age to have imposed upon himself as a duty the maintenance of an attitude of sceptical indifference and sarcastic criticism. He certainly succeeded. Although, as has been said, a man of singularly warm and affectionate feelings, he obtained the credit of being a cold-hearted cynic; and, although he was both independent and disinterested, he was abused as a hanger-on and toad-eater of the imperial court. Both imputations were wholly undeserved, and indeed were prompted to a great extent by the resentment felt by his literary equals on the other side at the cool ridicule with which he met them. But he deserved in some of the bad as well as many of the good senses of the term the phrase which we have applied to him of a man of the Renaissance. He had the warm partisanship and amiability towards friends and the scorpion-like sting for his foes, he had the ardent delight in learning and especially in matters of art and belles lettres, he had the scepticism, the voluptuousness, the curious delight in the contemplation of the horrible, which marked the men of letters of the humanist period. Like them he was a man of the world, and a man who without any baseness liked a king's palace better than a philosopher's hovel. Like them he had an acute judgment in matters of business, and like them a singular consciousness of the nothingness of things. Even his literary work has this Renaissance character. It is tolerably extensive, amounting to some seventeen or eighteen volumes, but its bulk is not great for a life which was not short, and which was occupied at least nominally in little else. About a third of it consists of the letters already mentioned, which will always be to those who delight in personal literature the most attractive part, and which, though in a fragmentary fashion, are really important as throwing side lights on history. Rather more than another third consists of the official work which has been already alluded to—reports, essays, short historical sketches, the chief of which latter is a history of Pedro the Cruel, and another of the curious pretender known in Russian story as the false Demetrius. Some of the literary essays, such as those on Beyle, on Turguenief, &c., where a personal element enters, are excellent. Against others and against the larger historical sketches—admirable as they are—M. Taine's criticism that they want life has some force. They are, however, all marked by Mérimée's admirable style, by his sound and accurate scholarship, his strong intellectual grasp of whatever he handled, his cool unprejudiced views, his marvellous faculty of designing and proportioning the treatment of his work. It is, however, in the remaining third of his work, consisting entirely of tales either in narrative or in dramatic form, and especially in the former, that his full power is perceived. He translated a certain number of things (chiefly from the Russian); but his fame does not rest on these, on his already-mentioned youthful supercheries, or on his later semi-dramatic works. There remain about a score of tales extending in point of composition over exactly forty years, and in length from that of *Colomba*, the longest, which fills about one hundred and fifty pages, to that of *L'Enlèvement de la Redoute*, which fills just half a dozen. They are unquestionably the best things of their kind written during the century, the only *nouvelles* that can challenge comparison with them being the very best of Gautier, and one or two of Balzac. The motives are sufficiently different. In *Colomba* and *Mateo Falcone*, the Corsican point of honour is drawn on; in *Carmen* (written apparently after reading Borrow's Spanish books), the gipsy character; in *La Vénus d'Ille* and *Lokis* (two of the finest of all), certain grisly superstitions, in the former case that known in a milder form as the ring given to Venus, in the latter a variety of the were-wolf fancy. *Arsène Guillot* is a singular satire full of sarcastic pathos on popular morality and religion; *La Chambre Bleue*, an 18th-century *conte*, worthy of Crébillon for grace and wit, and superior to him in delicacy; *The Capture of the Redoubt* just mentioned is a perfect piece of description; *L'Abbé Aubain* is again satirical; *La Double Méprise* (the authorship of which was objected to Mérimée when he was elected of the Academy) is an exercise in analysis strongly impregnated with the spirit of Stendhal, but better written than anything of that writer's. These stories, with his letters, assure Mérimée's place in literature at the very head of the French prose writers of the century. He had undertaken an edition of Brantôme for the Bibliothèque Elzévirienne, but it was never completed.

Mérimée's works have only been gradually published since his death. The latest, *The Letters to Panizzi*, which have also appeared in English, bears date 1881. There is as yet no uniform or handsome edition, but almost everything is obtainable in the collections of MM. Charpentier and Calmann Lévy. (G. SA.)

MERINO. See SHEEP and WOOL.

MERIONETH (Welsh *Meirionydd*), a maritime county of North Wales, is bounded N. by Carnarvon and Denbigh, S.E. by Denbigh and Montgomery, and W. by Cardigan Bay. It is triangular in shape, its greatest length north-east to south-west being 45 miles, and its greatest breadth north-west to south-east about 30 miles. The area is 385,291 acres, or about 600 square miles. Next to Carnarvon, Merioneth is the most mountainous county in Wales. If the scenery is less bold and striking than that of Carnarvon, it excels it in richness, variety, and picturesque beauty. Its lofty mountains are interpenetrated by dark deep dells or smiling vales. The outlines of its rugged crags are softened and adorned by rich foliage. The sea views are frequently fine, and rivers, lakes, and waterfalls add a romantic charm to the valleys. The highest summits in the county are the picturesque Cader Idris (which divides into three peaks,—one, Pen-y-Gadair, having an altitude of 2914 feet), Aran Fawddwy (2955), Arenig-fawr (2818), Moel-wyn (2566), Rhobell-fawr (2360). The finest valleys are those of Dyfi, Dysyni, Talyllyn, Mawddach, and Festiniog. The river Dyfrdwy or Dee rises 10 miles north-west of Bala, and, after passing through Bala Lake, flows north-east by Corwen to Denbighshire. The Dyfi rises in a small lake near Aran Fawddwy, and expands into an estuary of Cardigan Bay. The Mawddach or Maw, from the north of Aran Fawddwy, has a course of 12 miles south-west, during which it is joined by several other streams. The Dwyryd and other streams unite in forming the estuary of Traeth Bach. The finest waterfalls are the

Rhaiadr-y-Glyn near Corwen, Rhaiadr Du, and Pistyll Cain, the latter 150 feet high. The lakes are very numerous, but small, the largest being Bala Lake, or Pimblemere (in Welsh, Llyn Tegid, fair lake), 4 miles long by 1 broad, and Llyn Mwyngil (lake in a sweet nook) in the vale of Talyllyn. Both are much frequented by anglers. On account of frequent indentations the coast-line is about 100 miles long. Sandy beaches intervene between the rocky shores. Frequent shoals and sandbanks render navigation very dangerous. There are only two harbours of importance, Barmouth and Aberdovey.

A mountain tract of the county 15 miles from north to south by 10 from east to west, stretching from the coast inland, is of the Cambrian age, composed of grits, quartzose, and slates, and comprising the Merionethshire anticlinal. This tract is enclosed on the north, east, and south by the Menevian, Lingula, Tremadoc, and Arenig beds, which are pierced by numerous dykes and intrusive masses, mostly greenstone. Rhobell-fawr is one of the greatest igneous masses in the whole area of the Lingula beds. The Arenig beds are interstratified with and overlaid by accumulations of volcanic ashes, felspathic traps, or lava flows, which form the rugged heights of Cader Idris, the Arans, the Arenigs, Manod, and Moel-wyn; and these are in turn overlaid by the Llandeilo and Bala beds, the latter including the Bala limestone. Extensive slate quarries are worked near Festiniog, mostly underground, in strata of the Llandeilo age, giving employment to about 4000 men. Gold, lead, copper, and manganese have been obtained in various places.

Climate and Agriculture.—The climate varies much with the elevation, in some places being bleak and cold, and in others remarkably equable and genial. At Aberdovey it is proverbially mild, and the myrtle grows in the open air. All attempts to introduce fruits have proved abortive in most parts of the county. The soil is generally thin and poor, with fertile tracts in the valleys. A great portion of the moss has been reclaimed within late years.

According to the agricultural returns for 1882, there were 154,406 acres, or considerably less than half the total area, under cultivation. Of this as much as 119,133 acres were permanent pasture, and 13,755 under rotation grasses. Of the 17,312 acres under corn crops, 11,232 were under oats and 4807 under barley. Potatoes occupied 2392 acres, and turnips only 1496 acres. The area under woods extended to 15,049 acres.

The total number of horses in 1882 was 6088. A breed of ponies is peculiar to this county and Montgomeryshire. The rearing of horned cattle and dairy-farming are largely carried on, but the number of cattle (37,643) is considerably under the average of Wales generally. On the other hand the number of sheep in 1882 was 400,553, a larger number than in any other county of Wales, and much beyond the general average in the principality. They are a small hardy breed, which grow heavy fleeces. Goats frequent the loftier crags.

According to the latest return the number of proprietors was 1695, possessing 303,374 acres, with a gross annual value of £183,253. Of the owners 1044, or 62 per cent., possessed less than 1 acre, the average extent of the properties being 189 acres, and the average value per acre a little over 12s. There were ten proprietors who possessed over 5000 acres, viz., Sir W. W. Wynn, 20,295; R. J. L. Price, 17,718; T. P. Lloyd, 16,975; Mrs Kirkby, 13,410; Hon. C. H. Wynn, 10,504; A. J. G. Corbet, 9347; Sir E. Buckley, 8738; W. E. Oakeley, 6018; W. O. Gore, 5497; and R. M. Rickards, 5701.

Manufactures.—Woollen goods are manufactured in various places, especially at Dolgelly. They are principally coarse druggets, kerseymeres, and flannels. The knitting of stockings was a great industry at the close of last century, the value of the sales at Bala being estimated at from £17,000 to £19,000 annually.

Railways.—The Cambrian Railway skirts the coast from Portmadoc to Aberdovey. At Barmouth Junction a branch of the same crosses to Dolgelly, where it is joined by a branch of the Great Western Railway. Another branch of the Great Western unites Bala and Festiniog, and the latter place has railway connexion both with Llandudno Junction and with Portmadoc.

Administration and Population.—Merionethshire comprises five hundreds and thirty-three civil parishes. It has one court of quarter sessions, and the number of petty sessional divisions is six. Ecclesiastically it is partly in the diocese of Bangor, partly in that of St Asaph. The county returns one member to parliament. There is no municipal or parliamentary borough. The towns returned in 1881 as urban sanitary districts are Bala (1653), Barmouth (1512), Dolgelly (2457), Festiniog (11,272), and Towyn (3363). Since 1801 the population has nearly doubled. From 29,506 in that year it had increased in 1851 to 38,963, in 1871 to 46,598, and in 1881 to 54,793, of whom 27,576 were males, and 27,217 females.

History and Antiquities.—Originally Merioneth belonged to the territory of the Ordovices, and under the Romans it was included in *Britannia Secunda.* There are many Celtic, Roman, and mediæval remains. Caer Drewyn on the Dee, near Corwen, was a British camp. There are numerous cromlechs in various parts of the county, especially near the sea-coast. The *Via Occidentalis* of the Romans passed through Merioneth from south to north, and at Tomen-y-Mur was joined by a branch of the South Watling Street, the Castell Tomen-y-Mur being supposed to be identical with the Roman station of Heriri Mons. The immense ruin of Castel-y-Bere was originally one of the largest castles in Wales, but has not been occupied since the time of Edward I. During the Wars of the Roses the castle of Harlech, still a fine ruin, was held by the Lancastrians, and was the last in Wales to surrender. Of ecclesiastical remains the most important is Cymmer Abbey, founded by the Cistercians in 1198, a very fine ruin containing architecture of various periods from Norman to Perpendicular. There are numerous interesting old churches.

MERLIN. See Falcon.

MERMAIDS AND MERMEN, in the popular mythology of England and Scotland, are a class of beings more or less completely akin to man, who have their dwelling in the sea, but are capable of living on land and of entering into social relations with men and women.[1] They are easily identified, at least in some of their most important aspects, with the Old German Meriminni or Meerfrau, the Icelandic Hafgufa, Margygr, and Marmennill (mod. Marbendill), the Danish Hafmand or Maremind, the Irish Merrow or Merruach, the Marie-Morgan of Brittany and the Morforwyn of Wales;[2] and they have various points of resemblance to the vodyany or water-sprite and the rusalka or stream-fairy of Russian mythology. The typical mermaid (who is much more frequently described than the merman) has the head and body of a woman, usually of exceeding loveliness, but below the waist is fashioned like a fish with scales and fins. Her hair is long and beautiful, and she is often represented, like the Russian rusalka, as combing it with one hand while in the other she holds a looking-glass. At other times, like the rusalka, she is seen engaged in the more prosaic occupation of washing or beating clothes; but this, as, for example, in Hugh Miller's terrible Loch Slin legend, is a sign of some impending calamity. For a time at least a mermaid may become to all appearance an ordinary human being; and from a very striking Irish legend ("The Overflowing of Lough Neagh and Liban the Mermaid," in Joyce's *Old Celtic Romances*) it is evident that a human being may also for a time be transformed into a mermaid.

The mermaid legends, both English and other, may be grouped as follows. A. *A mermaid or mermaids either voluntarily or under compulsion reveal things that are about to happen.* Thus the two mermaids (merewîp) Hadeburc and Sigelint, in the *Nibelungenlied*, disclose his future course to the hero Hagen, who, having got possession of their garments, which they had left on the shore, compels them to pay ransom in this way. According to Resenius, a mermaid appeared to a peasant of Samsöe, foretold the birth of a prince, and moralized on the evils of intem-

[1] The name *mermaid* is compounded of the A.-S. *mere*, a lake, and *mægd*, a maid; but, though *mere wif* occurs in Beowulf, *mere-maid* does not appear till the Middle English period (Chaucer, *Romaunt of the Rose*, &c.). In Cornwall the fishermen say *merry-maids* and *merry-men.* The connexion with the sea rather than with inland waters appears to be of later origin. "The Mermaid of Martin Meer" (Roby's *Traditions of Lancashire*, vol. ii.) is an example of the older force of the word; and such "meer-women" are known to the country-folk in various parts of England (*e.g.*, at Newport in Shropshire, where the town is some day to be drowned by the woman's agency).

[2] See Rhys, "Welsh Fairy Tales," in *Y Cymmrodor*, 1881, 1882.

perance, &c. (*Kong Frederichs den andens Krönike*, Copenhagen. 1680, p. 302). B. *A Mermaid imparts supernatural powers to a human being.* Thus in the beautiful story of "The Old Man of Cury" (in Hunt's *Popular Romances of the West of England*, 1871) the old man, instead of silver and gold, obtains the power of doing good to his neighbours by breaking the spells of witchcraft, chasing away diseases, and discovering thieves. John Reid, the Cromarty shipmaster, was more selfish,—his "wishes three" being that neither he nor any of his friends should perish by the sea, that he should be uninterruptedly successful in everything he undertook, and that the lady who scorned his love should scorn it no more. C. *A mermaid has some one under her protection, and for wrong done to her ward exacts a terrible penalty.* One of the best and most detailed examples of this class is the story of the "Mermaid's Vengeance" in Mr Hunt's book already quoted. D. *A mermaid falls in love with a human being, lives with him as his lawful wife for a time, and then, some compact being unwittingly or intentionally broken by him, departs to her true home in the sea.* Here, if its mermaid form be accepted, the typical legend is undoubtedly that of *Melusina*, which, being made the subject of a full-fledged romance by Jean d'Arras, became one of the most popular folk-books of Europe, appearing in Spanish, German, Dutch, and Bohemian versions. Melusina, whose name may be a far-off echo of the Mylitta (Venus) of the Phœnicians, was married to Raymond of Lusignan, and was long afterwards proudly recognized as one of their ancestors by the Luxembourg, Rohan, and Sassenaye families, and even by the emperor Henry VII. Her story will be found in Baring Gould's *Myths of the Middle Ages.* E. *A mermaid falls in love with a man, and entices him to go and live with her below the sea; or a merman wins the affection or captures the person of an earthborn maiden.* This form of legend is very common, and has naturally been a favourite with poets. Macphail of Colonsay successfully rejects the allurements of the mermaid of Corrievrekin, and comes back after long years of trial to the maid of Colonsay.[1] The Danish ballads are especially full of the theme; as "Agnete and the Merman," an antecedent of Matthew Arnold's "Forsaken Merman"; the "Deceitful Merman, or Marstig's Daughter"; and the finely detailed story of Rosmer Hafmand (No. 49 in Grimm).

In relation to man the mermaid is usually of evil issue if not of evil intent. She has generally to be bribed or compelled to utter her prophecy or bestow her gifts, and whether as wife or paramour she brings disaster in her train. In itself her sea-life is often represented as one of endless delights, but at other times a mournful mystery and sadness broods over it. The fish-tail, which in popular fancy forms the characteristic feature of the mermaid, is really of secondary importance; for the true Teutonic mermaid—probably a remnant of the great cult of the Vanir—had no fish-tail;[2] and this symbolic appendage occurs in such remote mythological regions as to give no clue to historical connexion. The Tritons, and, in the later representations, the Sirens of classical antiquity, the Phœnician Dagon, and the Chaldæan Oannes are all well-known examples: the Ottawas and other American Indians have their man-fish and woman-fish (Jones, *Traditions of the North American Indians*, 1830); and the Chinese tell stories not unlike our own about the sea-women of their southern seas (Dennis, *Folklore of China*, 1875).

Quasi-historical instances of the appearance or capture of mermaids are common enough,[3] and serve, with the frequent use of the figure on signboards and coats of arms, to show how thoroughly the myth had taken hold of the popular imagination.[4] A mermaid captured at Bangor, on the shore of Belfast Lough, in the 6th century, was not only baptized, but admitted into some of the old calendars as a saint under the name of Murgen (*Notes and Queries*, Oct. 21, 1882); and Stowe (*Annales*, under date 1187) relates how a man-fish was kept for six months and more in the castle of Orforde in Suffolk. As showing how legendary material may gather round a simple fact, the oft-told story of the sea-woman of Edam is particularly interesting. The oldest authority, Joh. Gerbrandus a Leydis, a Carmelite monk (*ob.* 1504), tells (*Annales*, &c., Frankfort, 1620) how in 1403 a wild woman came through a breach in the dike into Purmerlake, and, being found by some Edam milkmaids, was ultimately taken to Haarlem and lived there many years. Nobody could understand her, but she learned to spin, and was wont to adore the cross. Ocka Scharlensis (*Chronijk van Friesland*, Leeuw., 1597) reasons that she was not a fish because she could spin, and she was not a woman because she could live in the sea; and thus in due course she got fairly established as a genuine mermaid. Vosmaer, who has carefully investigated the matter, enumerates forty writers who have repeated the story, and shows that the older ones speak only of a woman (see "Beschr. van de zoogen. Meermin der stad Haarlem," in *Verh. van de Holl. Maatsch. van K. en Wet.*, part 23, No. 1786). As for the stuffed mermaids which have figured from the days of Bartholomew Fair downwards, it is enough to mention that exhibited in the Turf Coffee-house, London, in 1822, and carefully drawn by Cruikshank (compare Chambers, *Book of Days*).

The best account of the mermaid-myth is in Baring Gould's *Myths of the Middle Ages.* See also, besides works already mentioned, Pontoppidan, who in his logically credulous way collects much matter to prove the existence of mermaids; Maillet, *Telliamed*, Hague, 1755; Grimm, *Deutsche Mythologie*, i. 404, and *Altdän. Heldenlieder*, 1811; Waldron's *Description* and Train's *Hist. and Stat. Acc. of the Isle of Man*; Folklore Society's *Record*, vol. ii.; Napier, *Hist. and Trad. Tales connected with the South of Scotland*; Sébillot, *Traditions de la Haute Bretagne*, 1882, and *Contes des Marins*, 1882. (H. A. W.)

MEROE, in classical geography (Strabo, xvii. 2, 2; Pliny, ii. 73, v. 10; Ptol., p. 201), was the metropolis of Æthiopia, situated on an island of the same name between the Nile and the Astaboras (Atbara). The "island" is only an inaccurate name for the fertile plain between the two rivers. This Meroe, first mentioned by Herodotus (ii. 29 *sq.*), succeeded an older Ethiopian kingdom of Napata lower down the Nile, originally subject to and civilized from Egypt, but which afterwards became independent and even sent forth an Ethiopian dynasty to reign in Egypt, to which the So and Tirhaka of the Bible belonged (see ETHIOPIA). The name of Meroe in the form Merawi is now given to Napata. The later Meroe retained its independence when Egypt fell under foreign sovereigns. Diodorus (iii. 6) describes it as entirely controlled by the priesthood till a native prince Ergamenes destroyed the sacerdotal caste in the time of Ptolemy II. Queen Candace (Acts viii. 27) was probably sovereign of Meroe; see Lepsius's *Letters*, Eng. tr., pp. 196, 206; and comp. Strabo, xvii. 1, 54 for

[3] Compare the strange account of the quasi-human creatures found in the Nile given by Theophylactus, *Historiæ*, viii. 16, pp. 299-302 of Bekker's ed.

[4] See the paper in *Jour. Brit. Arch. Ass.*, xxxviii., 1882, by H. S. Cuming, who points out that mermaids or mermen occur in the arms of Earls Caledon, Howth, and Sandwich, Viscounts Boyne and Hood, Lord Lyttleton, and Scott of Abbotsford, as well as in those of the Ellis, Byron, Phené, Skeffington, and other families. The English heralds represent the creatures with a single tail, the French and German heralds frequently with a double one.

a Queen Candace in Augustus's time when the Romans under Petronius advanced to Napata. Meroe was visited by Greek merchants; and the astronomical expedition of Eratosthenes determined its latitude with great accuracy. An exploring party in the reign of Nero found that the country below Meroe, formerly the site of many towns, had become almost wholly waste (Pliny, vi. 29). From the 6th to the 14th century of our era the Christian (Jacobite) realm of Dongola occupied the place of the older kingdom. The ruins of Meroe and Napata were fully explored by Lepsius in 1844, and the monuments are pictured in his *Denkmäler*.

MERSEBURG, the chief town of a district of the same name in the Prussian province of Saxony, is situated on the river Saale, 10 miles to the south of Halle and 17 to the west of Leipsic. It consists of a quaint and irregularly built old town, with two extensive suburbs, and contains six churches and several schools and charitable institutions. The cathedral is an interesting old pile, with a Romanesque choir of the 11th, a transept of the 13th, and a Late Gothic nave of the 16th century. Among its numerous monuments is that of Rudolph of Swabia, who fell in 1080 in an encounter with his rival Henry IV. It contains two paintings by Lucas Cranach. Contiguous to the cathedral is the Gothic chateau, formerly the residence of the Saxon princes and the bishops of Merseburg. The town-house, the post-office, and the "ständehaus" for the meetings of the provincial estates are also noteworthy buildings. The industries of Merseburg consist of the manufacture of card-board and coloured paper, dyeing, glue-boiling, machine-making, calico-printing, tanning, and brewing. Its population in 1880 was 15,205.

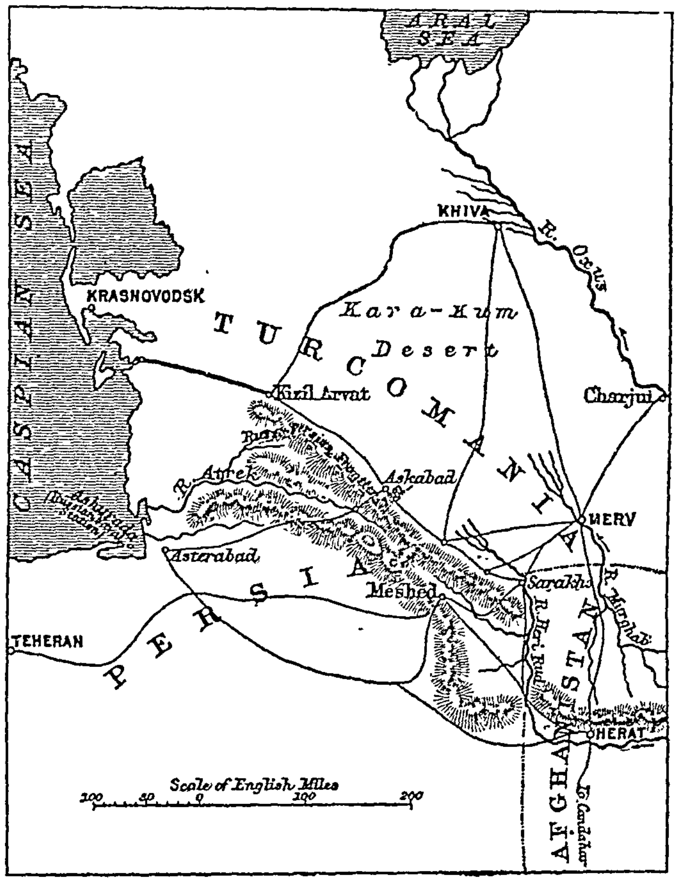
Merseburg (*i.e.*, "march-town") is one of the oldest towns in Germany. From the 9th century down to 1007 it was the capital of a countship of its own name, and from 968 to 1543 it was the seat of a bishop. In the 10th, 11th, and 12th centuries it was a favourite residence of the German emperors, and at this time its fairs enjoyed the importance afterwards inherited by those of Leipsic. The town was repeatedly visited by destructive conflagrations in the 14th to 17th centuries, and also suffered severely during the Thirty Years' War. From 1656 to 1738 it was the residence of the dukes of Saxe-Merseburg. The great victory gained by the emperor Henry I. over the Huns in 933 is believed to have been fought on the Keuschberg near Merseburg.

MERTHYR TYDFIL, or MERTHYR TYDVIL, a parliamentary borough and market-town of Glamorganshire, South Wales, is situated in a bleak and hilly region on the river Taff, and on several railway lines, 25 miles north-north-west of Cardiff and 30 east-north-east of Swansea. The town, which consists principally of the houses of workmen, is for the most part meanly and irregularly built, and at one time, on account of its defective sanitary arrangements, was frequently subject to epidemics of great severity. Within recent years great improvements have taken place, and the town now possesses both a plentiful supply of pure water and an excellent system of sewage. There are also some good streets with handsome shops, while in the suburbs there are a number of private residences and villas inhabited by the wealthier classes. Apart from its extensive iron and steel works, the town possesses no feature of interest. It is situated in the centre of the South Wales coal basin, and the rich coal-mines in the vicinity supply great facilities for the iron industries. At Merthyr Tydfil, which is said to have received its name from the martyrdom of a British saint Tydfil, there were smelting-works at a very early period, but none of any importance until 1755. From about forty years ago until 1875 the manufacture of bar iron developed with great rapidity, but since then the production of steel has largely taken its place. The borough returns two members to parliament. The population of the urban sanitary district in 1871 was 51,949, and in 1881 it was 48,857; the population of the parliamentary borough, which includes the parish of Aberdare and parts of the parishes of Llanwonno and Merthyr Tydfil and of Vainor (Brecon), and has an area of 29,954 acres, was in the same years 97,020 and 91,347.

MERV, MERU, or MAOUR,[1] a district of Central Asia, situated on the border-land of Iran and Turan.

The oasis of Merv lies in the midst of a desert, in about 37° 30′ N. lat. and 62° E. long. It is about 250 miles from Herat, 170 from Charjui on the Oxus, 360 from Khiva, and 175 from Gawars, the nearest point in the newly acquired (1881) Russian territory of Akhal.

The great chain of mountains which, under the name of Paropamisus and Hindu-Kush, extends across the Asiatic continent from the Caspian to China, and forms the line of ethnic demarcation between the Turanian and Indo-Germanic races, is interrupted at a single point; that point is on the same longitude with Merv. Through or near the



Neighbourhood of Merv.

trouée or gap which nature has created flow northward in parallel courses the rivers Heri-rud (Tejend) and Murghab, until they lose themselves in the desert of Kara-kum—that large expanse of waste, known also as Turcomania, which spreads at the northern foot of the mountains, and stretches from the lower Oxus to the Caspian.

Whether as a satrapy of Darius and subsequently as a province of Alexander, whether as the home of the Parthian race, whether as a bulwark against the destructive waves of Mongol invasion, or later as the glacis of Persian Khorasan, the valleys of those rivers—the district of Merv

[1] Merv is the modern Persian name. The river *Margus*, now the Murghab, on which was built the ancient city, is derived from *Margu*, the name of the province as recorded in the Behistan inscriptions of Darius. Spiegel connects the name *Margu* with old Bactrian *meregho*, bird, in allusion to the numerous swarms of birds that gather there. So, too, the river name Murghab means bird-water. The district appears to have been known in the 5th century as Marv-i-rud, so that the river was then the Marv. The name *Merûm* for the district occurs in the Armenian geography ascribed to Moses of Khorene, written probably in the 7th century (ed. Patkanoff). Maour is the Uzbek name, and of comparatively recent date.

—have ever been important outposts on the borders of Iran. In bye-gone epochs their banks have, under powerful rulers, been studded with populous and flourishing cities, which bore the name of "Sovereign of the Universe" (*Merv Shah-i-jehan*), and vied for fame with "Balkh, the Mother of cities"; of late times, with weakness or absence of government, those same banks have become choked with fallen battlements and ruins, the home of the snake and the jackal.

Merv has soared to prosperity or fallen to decay according to her political status at the moment, and history, which repeats itself, may yet have to sing her praises in the future as it has done in the past. All that human life in the desert requires is there,—water in abundance, and a soil unsurpassed for fertility. Good government is alone wanting to turn those natural gifts to full account.

The present inhabitants of the district are Turcomans of the Tekke tribe, who, like the other tribes inhabiting Turcomania, enjoyed until the approach of the Russians virtual independence, and acknowledged allegiance to no one,—a pastoral people who eked out a miserable existence by the trade of passing caravans, and in bad times pillaged the neighbouring and equally barbarous states, to whose reprisals they were in turn subjected.

From the year 1869, the date of the establishment of the Russian military settlement at Krasnovodsk on the east shore of the Caspian, the wave of Russian conquest has gradually swept eastwards along the northern frontier of Persia until it has for the moment stopped at the outermost border of the Akhal Turcoman country, which was incorporated in 1881 by Russia as the result of the defeat of that tribe at Geok Tepe. Among the districts still farther east, to which the Russians give the name of Eastern Turcomania, is that of the Merv Tekke Turcomans, kinsmen of the Akhal Tekkes, the most recent of Russia's subjects. The district of the Merv Tekkes may be taken to be that included between the lower Murghab below Yulutan, where the river enters the plain, and the Persian frontier from Sarakhs to Gawars.

A reference to the map will show the strategical importance of this district, situated at the point of meeting of two lines, of which one is the strategic line of Russian advance on Herat from Krasnovodsk to Sarakhs, and the other the strategic line of advance on the same place from Tashkend through Bokhara. The capital of the district is, moreover, the crossing-point of the Herat-Khiva and Meshed-Bokhara trade routes.

Consequently this district, a solitary oasis in a vast desert, guarantees to its possessor the command of an important avenue between north and south, and, in the event of its falling into Russian hands, will give that power in addition a valuable link in the chain of connexion between her recent acquisitions on the Persian frontier and those in Turkestan, the forging of which has been persistently advocated by Russian writers for years past. One of these, Colonel Veniukoff, frankly admits that it is the political results—"the consolidation of friendly relations with the Turcomans"—and not commercial interests merely, that are primarily looked to, and openly states that the forward movement in Central Asia "cannot end otherwise than by the annexation to Russia of the whole of Turan."

Whether by design or by the force of circumstances, the recommendations of those writers have been translated into facts, and Russia with her advanced post at Askabad is now within 400 miles of Herat, which Sir Henry Rawlinson designates as the key of India. The occupation of the Merv Tekke country would bring Russia to within 250 miles of Herat. From Askabad she is in connexion with the Caspian by a good line of communication, part of which from the sea to Kizil Arvat) is by rail; and hence facilities are offered for bringing up not only the resources of the Caucasus but of the whole of European Russia. While Russian troops are within 400 miles of Herat, the British troops at Quetta are more than 500 miles from Herat.[1]

These remarks serve to explain the very natural suspicion with which Great Britain has regarded the occupation one after another of important strategical points along that route by which alone Russia can strike at India,—the same line by which Napoleon meditated a Russo-French invasion in the early part of this century.

In the matter of Merv and the neighbouring Turcoman districts diplomacy has not been idle. As early as 1869, when an interchange of opinions was taking place between the Russian and British Governments with respect to the demarcation of a neutral zone between the two empires, Great Britain objected to the Russian proposal that this zone should be Afghanistan, "because of the near approach to India that would be thereby afforded to Russian troops from the direction of the Kara-kum, the home of the Turcomans, of which Merv is the central point." In the following year a Russian diplomatist remarked to the British ambassador at St Petersburg, when discussing the Afghan frontier, that great care would be required in tracing a line from *Khoja Saleh* on the *Oxus* to the south, as Merv and the country of the Turcomans were becoming "commercially important." About the same time Russia intimated that, if the amir of Afghanistan claimed to exercise sovereignty over the Tekkes, his pretensions could not be recognized. After the Russian campaign against Khiva in 1873, and the subsequent operations against the Turcomans, the English foreign secretary early in 1874 called attention "to the fears expressed by the amir of Afghanistan as to the complications in which he might become involved with Russia were the result of a Russian expedition against Merv to be to drive the Turcomans to take refuge in the province of Badghees in Herat." In reply to this communication Prince Gortschakoff repeated the assurance that the imperial Government "had no intention of sending any expedition against the Turcomans, or of occupying Merv." In 1875 the operations of General Lomakin on the northern frontier of Persia led to representations being made by the British ambassador at the court of St Petersburg. To these Russia replied that the czar had no intention of extending his frontiers on the side of Bokhara or on the side of Krasnovodsk. Notwithstanding the oft-repeated assurances to the contrary, large annexations have been since made in Turcomania by the Russians, and these proceedings, clearly indicating the persistent prosecution of a concerted plan, have naturally tended to disturb the harmonious relations which should subsist between the two great civilizing powers of the East.

Settlements and Inhabited Centres.—Of towns or even villages, fixed centres of habitation, there are none, according to Mr O'Donovan, the latest European traveller to Merv. The present political and military capital of Merv is Koushid Khan Kala, a fort which serves rather as a place of refuge against sudden attacks than as a habitation. It is situated on the east bank of the most westerly branch of the Murghab, about 25 miles below the dam at Porsa Kala. In form it is oblong, measuring 1¾ miles long by ¾ mile broad, is constructed entirely of earth, revetted on the exterior slope with sun-dried brick; the ramparts are 40 feet high, and are 60 feet at the base. The fort is built in a loop of the river, which protects it on two sides; between it and the river is an "obah," or nomad village of huts and tents, some thousand in number, disposed in rows, but there is no town or settlement.

Twenty-five miles east of Koushid Khan Kala lie the ruins of the Greek city of Antiochia Margiana, showing traces of a high civilization. According to Strabo (xi. 2) the Merv oasis at this period was surrounded with a wall measuring 1500 stadia (185 miles). Mr O'Donovan found the trace of the fort of Iskander to have been quadrangular, with a length of side of 900 yards. This was probably the fort built by Alexander, about 328 B.C., on his return from

[1] *Concurrently with the consolidation of her position in Turcomania*, Russia has of late been showing less military activity on the side of her Turkestan district. It is probable that her recent explorations at the sources of the Oxus have demonstrated the impracticability of directing any offensive movement against India from that side. Hence the line of strategical advance has been shifted from Tashkend to Tiflis.

Sogdiana after the capture of Bessus. The city was destroyed in 666 A.D. by the Arabs, who built a new one, afterwards known as Sultan Sanjar, about 1000 yards away, and occupying an area, according to Mr O'Donovan, of about 600 yards square. The towers are still extant, and inside can be seen the ruins of a most elaborate tomb, in which the supposed bones of Sultan Sanjar are enshrined. It has always been a place of pilgrimage for the faithful. Not far to the south-west lies the site of the last city of Merv, that which existed up to a hundred years ago, when it was laid waste by the Bokharians. It bears the name of its gallant defender Bairam Ali.

These three ruins are all that remain of that which flourished of yore as "sovereign of the universe."

At the time of the visit of Burnes, Abbott, Shakespear, and Taylour Thomson, about the fourth decade of the century, Merv was under the jurisdiction of Khiva, and the administrative centre was at Porsa Kala, where the dam is situated. This place is now also a waste of mud ruins, uninhabited.

Rivers.—The Heri-rud (or Tejend, as the river is named below Sarakhs) runs a course of some 280 miles within Afghan borders. On reaching the Persian frontier it turns north and forces a channel through the mountain chain near Sarakhs. Beyond Sarakhs the river is Turcoman on both banks, runs close to the Khelat mountains, and in the latitude of Askabad loses itself in the marshes formed by the spring floods. It is probably the Ochus of ancient geography, which watered Nissa, once the capital of Parthia, and joined the Oxus just before the latter river disembogued into the Caspian (Rennell's *Herodotus*). The Tejend is fordable at all points below Sarakhs except in the early spring after the melting of the snows. On the road from Meneh to Merv the river is sluggish, 50 yards wide and 4 feet deep in February. The river-bed is sunk 12 to 15 feet below the level of the surrounding country, and has immense quantities of drift wood on its banks; trees and luxuriant herbage clothe the immediate borders. At midsummer the river runs nearly dry, and does not reach Sarakhs. The Kashaf-rud, which flows near Meshed, is one of its chief affluents.

The Murghab takes its rise in the northern slopes of the Paropamisus, and runs parallel to the Heri-rud at a distance of 70 miles from it. On this river lies the plain or oasis of Merv, irrigated by means of an elaborate system of dams and canals cut from the main river. Beyond the limits of the oasis the Murghab "hides its streams in the sand," like the Tejend. The river at Porsa Kala (near the principal dam) is 80 yards wide, at Koushid Khan Kala 30 to 40 yards wide. In summer it is much swollen by the melting of the snows, and its stream is then barely fordable. The water is yellow in colour from suspended matter.

Formerly a great deal of the country, now a waste, between the two rivers was also cultivated by the agency of water derived from canals cut from the Tejend. These canals extended to Kucha Kum in the desert, rendering the journey between the two rivers much easier than in the present day. From the Murghab was also cut, among others, the Kara-i-ab canal, which ran for a distance of 40 miles towards the Tejend. Recent explorers affirm that there is no reason why these canals should not be again filled from those rivers, when the intervening country, "an argillaceous expanse" (O'Donovan), would become culturable.

Communication.—Merv is surrounded on all sides by desert. On the north, west, and east this desert is sandy and arid; water is exceedingly scarce, the wells being sometimes 60 or 70 miles apart, and easily choked. To the south of Merv, between the rivers Murghab and Tejend, there are traces of past cultivation, of irrigating canals, and of considerable settlements. Between the Tejend and Askabad the road lies through a populous well-cultivated country (Persian territory) by way of Kahka and Lutfabad.

There are no roads in Merv,—nothing but mere tracks. Many wide and deep irrigating canals have to be crossed; bridges are few and bad. The inhabitants cross by inflated skins.

The following tracks lead to the Persian frontier from Merv:—(1) *via* Mahmur or Chungul to Lutfabad—eight days on camels; (2) *via* Shahidli to Mehna—120 miles; (3) *via* Shahidli to Fort Cherkeshli and Meshed,—for 85 miles between the Murghab and Tejend there is scarcely any water; (4) *via* Sarakhs to Meshed, 9 or 10 marches for camels, and, according to Petrusevitch, without water between Merv and Sarakhs—120 miles.

To the Afghan frontier lead (1) the track *via* Sarakhs and up the Heri-rud to Herat—fit for a coach, according to Sir Charles MacGregor and Mr Lessar; and (2) a practicable track, used by Abbott and Shakespear, up the Murghab and Kushk rivers.

To the Oxus in Bokharian territory lead several tracks, the chief of which is that to Charjui—nine marches for camels. Water is scarce.

To Khiva by the direct track is 360 miles. Water is scarce.

Population.—The Turcomans, according to Sir Henry Rawlinson and others, are descendants of the Ghúz or Komani, a race of Turks who migrated westward from their homes in the Altai before the Christian era, and penetrated even to the Danube. From subsequent intermixture with Persian and Caucasian peoples, they exhibit variations from the true Tartar type. According to Baron de Bode the Turcoman closely resembles both in appearance and in speech the Nogai Tartar and the Tartar of Kasan on the Volga.

They are an independent race, as wild and free as their native desert, brave and very impatient of control—"Wild warriors in stormy freedom bred" (Moore). They have a very evil reputation for brigandage and murder, so much so that the Bokharians and Khivans have a proverb—"If you meet a viper and a Mervi, commence by killing the Mervi and then despatch the viper." Of late years a change for the better has taken place, and recent travellers among them state that the Mervis show an inclination to lead a more settled life and to establish an elementary form of government (Medjliss), and that it is no longer accounted an honour among them to kill their neighbours. Opium smoking and arrack drinking are apparently widespread vices (O'Donovan); at the same time they are described as clever and intelligent.

The Merv Tekkes (like the Akhal Tekkes) are classed in two great divisions—the Toktamish and the Otamish. Each of these divisions consists of two clans, and each clan is subdivided into families. The two clans of the Toktamish are called Beg and Wakil; those of the Otamish, Suchmuz and Bukshi. The clans of Beg and Wakil are the most powerful, and occupy that part of the oasis which lies on the right or east bank of the Murghab. The Suchmuz and Bukshi have their tents on the left or west bank.

There is no machinery of government, and no taxes are levied. Whatever government there be is of a patriarchal nature. Each family has a *ketkhoda* (patriarch), who represents the family in matters of policy, but can only act in accordance with the wishes of the clan. The *aksakals*, or grey beards, are also useful in settling intertribal disputes, but they are tolerated only so long as they do not act in opposition to the tribesmen. For external affairs and in time of war the *ketkhodas* exercise a certain amount of power. The authority of *ketkhodas* and *aksakals* is, however, overriden by the laws of custom or usage (*deb*) and the less respected laws of religion. The injunctions of deb are paramount. It sanctions the *alaman*, or plundering raid, and in general regulates the Turcoman's daily life; its prescriptions are more binding than those of the Koran.

The Tekkes marry young. The father purchases for his twelve-year-old son a child-wife for 500 to 2000 krans (£20 to £80). A young widow of twenty-five is much more valuable, but a woman over forty is not worth the price of a camel. On the conclusion of the bargain, the priest reads a prayer from the Koran, and the marriage becomes valid.

The dress of the men consists of a long tunic of coarse crimson silk reaching below the knees, with a white sash through which is stuck a dagger; an outer robe of brown camel-hair cloth, a huge sheepskin hat, trousers and slippers or amber-coloured knee-boots, complete the costume. The women are exceedingly fond of trinkets, rings, and amulets, which accompany their movements with a sound as it were of bells. Their dress consists of the same red silk robe as the men wear, with a sash round the waist, and high-heeled boots, red or yellow.

The religion is Suni Mohammedan; their language Jagatai or Oriental Turk.

The numbers of Merv Tekkes on the Murghab and Tejend are variously estimated, but may be stated approximately at 40,000 tents, including 5000 tents of the Salor tribe. These 40,000 tents represent a population of 200,000 to 250,000 souls. The Salors and Sariks at Yulutan and Panjdeh, higher up the Murghab, are given at 11,000 tents, or some 60,000 souls.

Products, Arts, and Manufactures.—The country in all times has been renowned throughout the East for its fertility. Strabo tells us "that it was not uncommon to meet with a vine whose stock could hardly be clasped by two men with outstretched arms, while

clusters of grapes might be gathered two cubits in length." The Arab traveller Ibn Haukal, writing in the 10th century, remarks that "the fruits of Merv are finer than those of any other place, and one cannot see in any other city such palaces with groves and streams and gardens." A local proverb says, "Sow a grain to reap a hundred." All cereals and many fruits grow in great abundance.

The Turcomans possess a famous breed of horses,—not prepossessing in appearance, being somewhat leggy and long in the back and neck, but capable of accomplishing long distances—50 or 60 miles—for several days in succession, and with very little food. Their great peculiarity appears to be their hairlessness; the coat is very fine, the mane and tail very scanty. This breed of horses, as well as the wealth of the Merv Tekkes in camels and flocks, is fast disappearing.

The Turcomans are noted as excellent workers in silver and as armourers, and their carpets are superior to Persian. They also make felts and a rough cloth of sheep's wool.

One of the chief occupations of the male sex is the repair of the dams and the clearing of the canals, upon the efficiency of which their existence is dependent. The services of a large number of workmen are always held in readiness for the purpose. In 1878 the unusual mass of water in the Murghab carried away the dam, and the drying up of some of the canals nearly led to a failure of the crops.

Climate.—The position of Merv, in the midst of sandy deserts in the heart of Asia, makes the climate in the heat of summer most oppressive. The least wind raises clouds of fine sand and dust, which fill the air, render it so opaque as to obscure the noonday sun, and make respiration difficult. In winter the climate is very fine. Snow falls rarely, and melts at once.

History.—The name Merv, or some similar form, occurs at a very early period in the history of the Aryan race. Under Mouru we find it mentioned with Bakhdi (Balkh) in the geography of the Zend Avesta (*Vendidad*, fargand i., ed. Spiegel), which dates probably from a period anterior to the conquest of Bactria by the Assyrians, and therefore at least one thousand two hundred years before the Christian era. Under the name of Margu it occurs in the cuneiform inscriptions of Darius Hystaspis, where it is referred to as forming part of one of the satrapies of the ancient Persian empire (*Inscriptiones Behistani*, ed. Kossowicz). It afterwards became a province (Μαργιανή) of the Græco-Syrian, Parthian, and Persian kingdoms. On the Margus—the Epardus of Arrian and now the Murghab—stood the capital of the district, Antiochia Margiana, so called after Antiochus Soter, who rebuilt the city founded by Alexander the Great. About the 5th century, during the dynasty of the Sasanids, Merv was the seat of a Christian archbishopric of the Nestorian Church. In the middle of the 7th century the flood of Arab conquest swept over the mountains of Persia to the deserts of Central Asia. Merv was occupied 666 A.D. by the lieutenants of the caliph Othman, and was constituted the capital of Khorasan. From this city as their base the Arabs, under Kuteibe bin Muslim, early in the 8th century brought under subjection Balkh, Bokhara, Ferghana, and Kashgaria, and penetrated into China as far as the province of Kan-su. In the latter part of the 8th century Merv became obnoxious to Islam as the centre of heretical propaganda preached by Mokannah (Haschem ben Hakem), the "veiled prophet of Khorasan," who claimed to be the incarnation of the Deity. In 874 Arab rule in Central Asia came to an end. During their dominion Merv, like Samarkand and Bokhara, became one of the great schools of science, and the celebrated historian Yakut studied in its libraries. About 1037 the Seljukian Turks crossed the Oxus from the north and raised Toghrul Beg, grandson of Seljuk, to the throne of Persia, founding the Seljukian dynasty, with its capital at Nishapur. A younger brother of Toghrul, Daoud, took possession of Merv and Herat. Toghrul was succeeded by the renowned Alp Arslan (the great lion), whose sway was so vast that, according to tradition, no fewer than twelve hundred kings, princes, and sons of kings and princes did homage before his throne. Alp Arslan was buried at Merv. It was about this time that Merv reached the zenith of her glory. During the reign of Sultan Sanjar of the same house, towards the middle of the 11th century, Merv was overrun by the Turcomans of Ghúz, and the country was reduced to a state of misery and desolation. These Turcomans, the ancestors of the present tribes of Turcomania, were probably introduced into the country by the Seljukian Turks as military colonists. They formed the van of their armies, and rendered efficient service so long as the dynasty lasted, and afterwards took part in the wars of Tamerlane.

In 1221 Merv opened its gates to Toolai, son of Jenghiz, khan of the Mongols, on which occasion the inhabitants, to the number of 700,000, are said to have been butchered. From this time forward Merv, which had been the chief city of Khorasan, and was popularly supposed to contain a million inhabitants, commenced to languish in obscurity. In the early part of the 14th century Merv was again the seat of a Christian archbishopric of the Eastern Church. On the death of the grandson of Jenghiz Khan Merv became included in the possessions of Toghluk Timur Khan (Tamerlane), in 1380. In 1505 the decayed city was occupied by the Uzbeks, who five years later were expelled by Ismail Khan, the founder of the Suffavean dynasty of Persia. Merv thenceforward remained in the hands of Persia until 1787, when it was attacked and captured by the emir of Bokhara. Seven years later the Bokharians razed the city to the ground, broke down the dams, and converted the district into a waste. About 1790 the Sarik Turcomans pitched their tents there. When Sir Alexander Burnes traversed the country in 1832, the Khivans were the rulers of Merv, the nomad population being subject to them. About this time the Tekke Turcomans, then living at Orazkala on the Heri-rud, were forced to migrate northward in consequence of the pressure from behind of the Persians. The Khivans contested the advance of the Tekkes, but ultimately, about the year 1856, the latter became the sovereign power in the country, and have ever since resisted all attempts at reconquest.

Authorities.—Besides the standard travels of Wolff, Ferrier, Vambery, Burnes, Abbott, Mouravieff, and others, the following works and papers of more recent date may be consulted with advantage:—Sir H. Rawlinson's *England and Russia in the East*; O'Donovan's correspondence with the *Daily News*, 1880-81; O'Donovan's "Merv," *Proc. Roy. Geog. Soc.*; Col. Stewart's "Country of the Tekke Turcomans," *Proc. Roy. Geog. Soc.*, with excellent map; "The New Russo-Persian Frontier, 1881," *Proc. Roy. Geog. Soc.*; Girard de Rialle, *Mémoire sur l'Asie Centrale*; Sir H. Rawlinson, "Road to Merv," *Proc. Roy. Geog. Soc.*; Col. Baker's *Clouds in the East*; Captain Napier's "Reports," *Jour. Roy. Geog. Soc.*; Hutton's *Central Asia*; Marvin's *Merv*; Col Potto's *Steppe Campaigns*; Sir Charles MacGregor's *Journey through Khorassan*; Boulger's *England and Russia in Central Asia*; Captain Butler's *Communications to the Public Press*; Lessar's "Journeys," *Proc. Roy. Geog. Soc.*; O'Donovan's *Merv Oasis*; Papers on the Turcomans, &c., by Col. Petrusevitch, *Proc. Imp. Russ. Geog. Soc.*, Caucasus section; Col. Grodekoff's *Journey from Tashkend to Persia*, 1880; Captain Kuropatkin's *Turcomania*, 1880; Col. Veniukoff's *Progress of Russia in Central Asia*, 1877, and other papers by the same author; Col. Kostenko's "Turkestan," *Jour. R. U. S. Instn.*; Schuyler's *Turkistan*; correspondence on Central Asia presented to parliament, &c. (F. C. H. C.)

MÉRYON, CHARLES (1821–1868). The name of Méryon is associated with that spirited revival of etching in France which took place in the middle of the 19th century,—say from 1850 to 1865,—but it is rather by the individuality of his own achievements, and the strength of his artistic nature, than by the influence he exercised that Méryon best deserves fame. No doubt his work encouraged others to employ the same medium of expression, and so great was his own perfection of *technique* that he may well have been made a model; but, after all, the medium he selected, and in which he excelled, was but the accident of his art; he was driven to it in part by stress of circumstances—by colour blindness; and, even with colour blindness, his extraordinary certainty of hand and his delicate perception of light, aided by his potent imagination, would have made him a great draughtsman not alone upon the copper.

Charles Méryon was born in Paris in 1821. His father was an English physician, his mother a French dancer. It was to his mother's care that Méryon's childhood was confided. She was supplied with money, and she gave the boy passionate affection, if not a wise training. But she died when he was still very young, and Méryon in due time entered the French navy, and in the corvette "Le Rhin" made the voyage round the world. He was already a draughtsman, for on the coast of New Zealand he made pencil drawings which he was able to employ, years afterwards, as studies for etchings of the landscape of those regions. The artistic instinct developed, and, while he was yet a lieutenant, Méryon left the navy. Finding that he was colour-blind, Méryon determined to devote himself to etching. He entered the work-room of one Bléry, from whom he learnt something of technical matters, and to whom he always remained grateful. Méryon was by this time poor. It is said that he might have had assistance from his kindred, but he was too proud to ask it. And thus he was reduced to the need of executing for the sake of daily bread much work that was wholly mechanical and irksome. Resolutely, though unwillingly, he became the hack of his art, doing frequently, from the day when he was first a master of it to the day when insanity disabled him, many dull commissions which paid ill, but paid better than his original works. Among learner's work, done for his own advantage, are to be counted some studies after the

Dutch etchers such as Zeeman and Adrian van de Velde. Having proved himself a surprising copyist, he proceeded to labour of his own, and began that series of etchings which are the greatest embodiments of his greatest conceptions—the series called "Eaux-fortes sur Paris." These plates, executed from 1850 to 1854, are never to be met with as a set; they were never expressly published as a set. But they none the less constituted in Méryon's mind an harmonious series. For him their likenesses and their contrasts were alike studied; they had a beginning and an end; and their differences were lost in their unity.

Besides the twenty-two etchings "sur Paris" characterized below, Méryon did seventy-two etchings of one sort and another,—ninety-four in all being catalogued in Wedmore's *Méryon and Méryon's Paris*; but these include the works of his apprenticeship and of his decline, adroit copies in which his best success was in the sinking of his own individuality, and dull and worthless portraits chiefly of forgotten celebrities. Yet among the seventy-two prints outside his professed series there are at least a dozen that will aid his fame. Three or four beautiful etchings of Paris do not belong to the series at all. Two or three etchings, again, are devoted to the illustration of Bourges, a city in which the old wooden houses were as attractive to him for their own sakes as were the stone-built monuments of Paris. But generally it was when Paris engaged him that he succeeded the most. He would have done more work, however,—though he could hardly have done better work,—if the material difficulties of his life had not pressed upon him and shortened his days. He was a bachelor, unhappy in love, and yet, it is related, almost as constantly occupied with love as with work. The depth of his imagination and the surprising mastery which he achieved almost from the beginning in the technicalities of his craft were appreciated only by a few artists, critics, and connoisseurs, and he could not sell his etchings, or could sell them only for about 10d. a piece. The fact that his own original work was of incalculably greater value than his best copies of his most celebrated forerunners had not yet impressed itself upon anybody. Disappointment told upon him, and, frugal as was his way of life, poverty must have told on him. He became subject to hallucinations. Enemies, he said, waited for him at the corners of the streets; his few friends robbed him or owed him that which they would never pay. A very few years after the completion of his Paris series, he was lodged in the madhouse of Charenton. Its order and care restored him for a while to health, and he came out and did a little more work, but at bottom he was exhausted. In 1867 he returned to his asylum, and died there in 1868. In the middle years of his life, just before he was placed under confinement, he was much associated with Bracquemond and with Flameng,—skilled practitioners of etching, while he was himself an undeniable genius,—and the best of the portraits we have of him is that one by Bracquemond under which the sitter wrote that it represented "the sombre Méryon with the grotesque visage." And it did.

There are twenty-two pieces in the Eaux-fortes sur Paris. Some of them are insignificant. That is because ten out of the twenty-two were destined as headpiece, tailpiece, or running commentary on some more important plate. But each has its value, and certain of the smaller pieces throw great light on the aim of the entire set. Thus, one little plate—not a picture at all—is devoted to the record of verses made by Méryon, the purpose of which is to lament the life of Paris. The misery and poverty of the town Méryon had to illustrate, as well as its splendour. The art of Méryon is completely misconceived when his etchings are spoken of as views of Paris. They are often "views," but they are so just so far as is compatible with their being likewise the visions of a poet and the compositions of an artist. It was an epic of Paris that Méryon determined to make, coloured strongly by his personal sentiment, and affected here and there by the occurrences of the moment,—in more than one case, for instance, he hurried with particular affection to etch his impression of some old-world building which was on the point of destruction. Nearly every etching in the series is an instance of technical skill, but even the technical skill is exercised most happily in those etchings which have the advantage of impressive subjects, and which the collector willingly cherishes for their mysterious suggestiveness or for their pure beauty. Of these, the Abside de Notre Dame is the general favourite; it is commonly held to be Méryon's masterpiece. Light and shade play wonderfully over the great fabric of the church, seen over the spaces of the river. As a draughtsman of architecture, Méryon was complete; his sympathy with its various styles was broad, and his work on its various styles unbiassed and of equal perfection—a point in which it is curious to contrast him with Turner, who, in drawing Gothic, often drew it with want of appreciation. It is evident that architecture must enter largely into any representation of a city, however much such representation may be a vision, and however little a chronicle. Besides, the architectural portion even of Méryon's labour is but indirectly imaginative; to the imagination he has given freer play in his dealings with the figure, whether the people of the street or of the river or the people who, when he is most frankly or even wildly symbolical, crowd the sky. Generally speaking, his figures are, as regards draughtsmanship, "landscape-painter's figures." They are drawn more with an eye to grace than to correctness. But they are not "landscape-painter's figures" at all when what we are concerned with is not the method of their representation but the purpose of their introduction. They are seen then to be in exceptional accord with the sentiment of the scene. Sometimes, as in the case of La Morgue, it is they who tell the story of the picture. Sometimes, as in the case of La Rue des Mauvais Garçons,—with the two passing women bent together in secret converse,—they at least suggest it. And sometimes, as in L'Arche du Pont Notre Dame, it is their expressive gesture and eager action that give vitality and animation to the scene. Dealing perfectly with architecture, and perfectly, as far as concerned his peculiar purpose, with humanity in his art, Méryon was little called upon by the character of his subjects to deal with Nature. He drew trees but badly, never representing foliage happily, either in detail or in mass. But to render the characteristics of the city, it was necessary that he should know how to pourtray a certain kind of water—river-water, mostly sluggish—and a certain kind of sky—the grey obscured and lower sky that broods over a world of roof and chimney. This water and this sky Méryon is thoroughly master of; he notes with observant affection their changes in all lights.

Méryon's excellent draughtmanship, and his keen appreciation of light, shade, and tone, were, of course, helps to his becoming a great etcher. But a living authority, himself an eminent etcher, and admiring Méryon thoroughly, has called Méryon by preference a great original engraver,—so little of Méryon's work accords with Mr Haden's view of etching. Méryon was anything but a brilliant sketcher; and, if an artist's success in etching is to be gauged chiefly by the rapidity with which he records an impression, Méryon's success was not great. There can be no doubt that his work was laborious and deliberate, instead of swift and impulsive, and that of some other virtues of the etcher—"selection" and "abstraction" as Mr Hamerton has defined them—he shows small trace. But a genius like Méryon is a law unto himself, or rather in his practice of his art he makes the laws by which that art and he are to be judged. He was a great etcher, and by his most elaborate labour he seemed somehow to ensure the more completely for his picture that virtue of unity of impression which, it may well be admitted, oftener belongs to rapid than to deliberate work. In Méryon's etchings the hand-work never seems to be in arrear of the thought. As long as the hand-work must continue, the thought and passion are retained. Méryon knows the secrets of his craft as well as did the older masters of it; but he turns them to his own purposes. He is unexcelled in strength and in precision, nor is he often rivalled in delicacy. These qualities, and others more distinctly technical, which it would take too long to insist on here, students find in his etchings. But the incommunicable charm of Méryon's prints and their lasting fascination are due to the fact that, behind all technical qualities, and as their very source and spring, there lies the potent imagination of the artist, poetical and vivid, directing him what to see in his subject, and how to see it. (F. WE.)

MESCHERYAKS, or MESCHERS, a people inhabiting eastern Russia. Nestor regarded them as Finns, and even now part of the Mordvinians (of Finnish origin) call themselves Meschers. Klaproth, on the other hand, supposed they were a mixture of Finns and Turks, and the Hungarian traveller Reguli discovered that the Tartarized Meschers of the Obi closely resembled Hungarians. They formerly occupied the basin of the Oka (where the town Meschersk, now Meschovsk, has maintained their name) and of the Sura, extending north-east to the Volga. After the conquest of the Kazan empire by Russia, part of

them migrated north-eastwards to the basins of the Kama and Byelaya, and thus the Meschers divided into two branches. The western branch became Russified, so that the Mescheryaks of the governments of Penza, Saratoff, Ryazan, and Vladimir have adopted the customs, language, and religion of the conquering race; but their ethnographical characteristics can be easily distinguished in the Russian population of the governments of Penza and Tamboff. The eastern branch has taken on the customs, language, and religion of Bashkirs, with whom their fusion is still more complete. They can be distinguished from their neighbours only by their more peaceful character. This Bashkir-Mescheryak branch was estimated by Rittich in 1875 to number 138,000. They make 6 per cent. of the population of the government of Upa, and 22 per cent. in the district of Birsk. The number of the western Mescheryaks is unknown, and could hardly be estimated on account of their mixture with Russians. It is only in the government of Penza that they have maintained their national features; there they make 3 per cent. of the population.

MESCHOVSK, a district town of Russia, in the government of Kaluga, 45 miles to the south-west of the capital of the province. It is an old town supposed to date from the 13th century, and it is often mentioned in Russian annals under the names of Mezetsk, Mezechevsk, or Meschorsk. About the end of the 14th century it was embraced in Lithuania, and it was ceded to the Moscow "great principality" in 1494. It was often pillaged by Tartars in the 16th century, and during the great disturbances of 1610 all its inhabitants were killed by the Zaporoghi Cossacks, and the fort was taken by Poles, who returned it to Russia only after the treaty of Deulin. The country round Meschovsk is not fertile; but, from its position on old established routes to the south, the town has become a centre of considerable trade. Its annual fair, which takes place on the grounds of the very old Petrovsk monastery, is important to the surrounding districts for the export sale of horses, grain, hemp, hempseed oil, and coarse linen, and for the import trade in cottons, woollens, and earthen and glass wares, the whole turn-over reaching about £100,000. Population, 7400.

MESHED (properly Mesh-hed, *i.e.*, "place of martyrdom," "shrine"), a city of northern Persia, capital of Khorásán, 472 miles east of Tehrán, 201 miles north-west of Herat, 36° 17′ 40″ N., 52° 35′ 29″ E., lies on a plain watered by the Keshaf-rúd, a tributary of the Heri-rúd, and is surrounded by mud walls 4 miles in circumference, with a dry ditch 40 feet deep at some points, which could be flooded from the neighbouring reservoir and watercourses. Within this enclosure is a strong citadel, with good walls 25 feet high, residence of the prince governor of Khorásán. There are five gates, from one of which, the Bala Khíabán, the Khíabán main street runs right through the city, forming a fine boulevard planted with plane and mulberry trees, and with a stream of dirty water running down its whole length. In the centre is an open parallelogram 160 yards by 75, encircled by double-storied cloisters, and pierced on the long side by a high arched porch leading directly to the great mosque, whose gilded dome rises above the shrine of the famous Imám Rizá.[1] The marble tomb of the saint, which is the most venerated spot in the whole of Persia, and yearly visited by from 80,000 to 100,000 pilgrims, is surrounded by a silver railing, and approached by a flight of inlaid marble steps. Eastwick, the only European before O'Donovan who penetrated as far as the parallelogram, describes the mosque as large enough to contain three thousand people. It is flanked by two gilded minarets, one of which, 120 feet high, is extremely beautiful, with an exquisitely carved capital, built by Sháh Abbás. The façade is entirely covered with blue and white enamelled tiles. To the mosque are attached as many as two thousand attendants and retainers of all sorts, including no less than five hundred mollahs. Beyond the dome is Gauhar Sháh's handsome mosque, surmounted by an immense blue dome, and also flanked by two minarets. In the main street is a public kitchen supported by the enormous revenues of the shrine, where eight hundred devotees are daily supplied with food gratuitously. The only other notable buildings in the place are some colleges and twenty-two caravanserais, one of which is of great size. Meshed does a considerable local and transit trade to the yearly value of about 600,000 tománs, and its bazaars are always well stocked with silks, velvets, felts, cottons, shawls, carpets, lacquer work, lambskins, hardware, glass, china, and other goods from South Persia, India, Turkestan, and Russia. The European trade is now entirely controlled by Russia, and European manufactured articles are mostly all from that country. The chief manufactures are silk, satin, velvet, and checked-cotton fabrics, carpets, shawls, noted sword blades, shagreen, and turquois jewellery. Within the enclosures are extensive cemeteries far exceeding the local requirements, large numbers of the faithful being brought from all parts of the Shí'a world to be buried in the vicinity of Rizá's shrine under the belief that their eternal salvation is thereby ensured.

Some 10 miles west of Meshed is a powder factory, formerly under Colonel Dolmage, where powder of excellent quality is produced. The district, although fertile, does not produce sufficient for the inhabitants, so that much grain has to be imported from Kurdistán and Nisháp-úr. The climate is very severe in winter, with much snow; in summer it is less sultry than might be expected, the temperature ranging from 76° F. to 90° or 92° F., and in exceptional years 94° to 98° F. The population is variously estimated at from 45,000 (Connolly) and 60,000 (Ferrier) to 80,000 and 100,000 (Eastwick). The settled residents, exclusive of pilgrims and foreign traders, are estimated by O'Donovan at 50,000.

The main caravan routes from Khiva, Bokhara, Samarkand, and Herat converge at Meshed, whence lines of traffic radiate to Kúchan for the Atrek valley and the Caspian, to Nishápúr and Bostam for Tehrán, to Tabas for Isfahán, to Khaf for Sístán and Kirmán. It thus occupies a position in north-eastern Persia analogous to that of Tabríz in the north-west.

MESHED-ALI, *i.e.*, the shrine of the "martyr" Ali, is a town of Asiatic Turkey, province of Baghdad, 50 miles south of Kerbela, close to the ruins of Kufa, and 2 miles west of the Hindíye branch of the Euphrates, the reputed burial-place of the caliph Ali.[2] It stands on the east scarp of the Syrian desert, and is enclosed by nearly square brick walls flanked by massive round towers dating from the time of the caliphs. Under the gilded dome of the great mosque, which occupies the centre of the town, is the shrine of Ali, which is held by the Shí'a as at least as holy as the Kaaba itself. Any Moslem buried within sight of the dome being certain of salvation, large numbers of bodies are yearly sent from all parts for interment here. Besides the mosque with its richly decorated façade, the only noteworthy building is a good bazaar supplied from Baghdad and Basra. The town itself, which Lady Anne

[1] 'Alí Riẓá (or el-Riḍá), the eighth imám of the Shí'a, is the 'Alí ibn Músá from whom the party of Alides had such hopes under the caliphate of Mamún (see MOHAMMEDANISM). He died at Ṭús, 818 A.D., and was buried by Mamún's orders in the vicinity of that town beside the grave of Hárún el-Rashíd. To the Alides he was a martyr, being believed to have been poisoned by the caliph. Ibn Batúta, who describes both shrines (iii. 77 *sq.*), tells how the pious visitors to the shrine of 'Alí ibn Músá used to spurn with their feet the tomb of Rashid. In his time a considerable town had been formed around the shrine under the name of Meshhed el-Riḍá and ultimately the new town eclipsed the older city of Ṭus.

[2] Whether the place really contains the grave of Ali was long disputed, and the story given in defence of its claims is doubtless apocryphal. The dome was built under the Abbasids, and the resting-place of the caliph unknown or concealed under the Omayyads (Ibn Ḥaukal, p. 163).

Blunt describes as "an ideal Eastern city, standing in an absolute desert, and bare of all surroundings but its tombs," consists of narrow gloomy streets lined by houses closely packed together. The locality is properly named Najaf, and gives its name to the neighbouring lake, a large depression filled by an eruption of the river, and ranging from 6 to 20 feet in depth. The accumulated treasures of the shrine were carried off by the Wahhábites when they captured this place early in the present century. The population is estimated at 7000, including several Indian Mohammedans under the protection of the British resident at Baghdad.

The aspect of the shrine in the 14th century is described by Ibn Batúta, i. 414 *sq.* A plan of the town and description of its splendour before the Wahhábites pillaged it is given by Niebuhr. See also Ibn Jubair, p. 214; P. Teixeira, *Itin.*, cap. iv.

MESHED HOSEIN, properly MESHHED ḤOSEIN. See KERBELA, vol. xiv. p. 48.

MESMER, MESMERISM. See vol. xv. p. 277.

e Plate II. MESOPOTAMIA, the "country between the rivers," is a purely geographical expression, the countries which it comprehends never having formed a self-contained political unity.[1] It was first introduced by the Greeks at or after the time of Alexander, but probably had its origin in the earlier Aramæan name *bêth nahrîn* (the country between the rivers), to which again corresponds the Biblical *Aram Naharayim*.[2] As early as 700 B.C. "the country of two rivers" is mentioned on the Egyptian monuments under the name Naharina, but no such designation appears in the cuneiform inscriptions (though the territory formed part of the Assyrian as it afterwards did of the Persian empire). The most settled period in the history of Mesopotamia was probably under Persian-Greek rule. Xenophon applies the name Syria to the extremely fertile district which he traversed after having crossed the Euphrates at Thapsacus. The country beyond the Araxes (Chaboras ?) he calls Arabia,—a desert region in which his army had to suffer great hardships until it reached the "gates of Arabia." Even in later times Mesopotamia was included under the name Assyria, or was reckoned part of Babylonia.

These statements of Xenophon already indicate a demarcation of the territory afterwards called Mesopotamia, as well as its division into two sections. The fertile portion, inhabited by agricultural Aramæans, stretched from the Euphrates to the Chaboras; the desert portion, the home of wandering tribes, extended to the Tigris. It would be rash, however, to conclude from this that Mesopotamia designated the whole territory between the Euphrates and Tigris; indeed it is possible that *Aram Naharayim*, the Aram of the country of the two rivers, originally meant only the main portion of the fertile country inhabited by Syrians. In this case the two boundary rivers must have been, not the Euphrates and the Tigris, but the Euphrates and the Chaboras. After the final occupation of the country by the Romans (156 A.D.), the political province of Mesopotamia was practically confined to this more limited district. Though in ordinary usage the Euphrates and Tigris are considered as the two rivers which bound Mesopotamia, the one bank of the river cannot be geographically separated from the other, and consequently narrow strips of country on the right bank of the Euphrates and on the left bank of the Tigris must be reckoned to the country "between" the rivers. On the other hand, the country between the sources of the Euphrates and the Tigris has from early times been reckoned not to Mesopotamia but to Armenia. In this direction the Masius range forms the proper boundary, and it is only on rare occasions that theoretical geographers extend the name Mesopotamia over the more northern districts, Sophene, &c. Purely theoretical too, and not to be approved, is the extension of the definition so as to include the land of Babylonia ('Irák 'Arabi), that is, the country as far south as the confluence of the Euphrates and Tigris, or even as far as their embouchure in the Persian Gulf.

From what has been said it appears that Mesopotamia reaches its northern limits at the points where the EUPHRATES (*q.v.*) and the Tigris break through the mountain range and enter the lowlands. In the case of the Euphrates this takes place at Sumeisát (Samosata), in that of the Tigris near Jezíret ibn 'Omar (Bezabdá) and Mosul (Nineveh). Consequently the irregular northern boundaries are marked by the lowland limits of those spurs of the Taurus mountains known in antiquity as Mons Masius and now as Ḳaraje Dágh and Ṭúr 'Abdín. Towards the south the ancient boundary was the so-called Median Wall, which, near Pirux Shapur, not much to the south of Hít (the ancient Is), crossed from the Euphrates in the direction of Ḳadisiya (Opis) to the Tigris. There the two rivers approach each other, to diverge again lower down. At the same place begins the network of canals connecting the two rivers which rendered the country of Babylonia one of the richest in the world; there too, in a geological sense, the higher portion of the plain, consisting of strata of gypsum and marl, comes to an end; there at one time ran the line of the sea-coast; and there begin those alluvial formations with which the mighty rivers in the course of long ages have filled up this depressed area. Mesopotamia thus forms a triangle lying in the north-west and south-east direction, with its long sides towards the north and south-west. It extends from 37° 30′ to about 33° N. lat. and from 38° to 46° E. long., and has an area of some 55,200 square miles. The points at which the rivers issue from among the mountains have an absolute altitude of between 1000 and 1150 feet, and the plain sinks rapidly towards the southern extremity of Mesopotamia, where it is not more than about 165 feet above the sea. As a whole the entire country consists of a single open stretch, save that in the north there are some branches of the Taurus—the Nimrúd Dágh near Orfá, the long limestone range of 'Abd-el 'Azíz, running north-north-west, and farther to the east the Sinjar range, also of limestone, 7 miles broad and 50 miles long, running north-north-east. Between these two ranges—near the isolated basaltic hill of Tell Kókab (Hill of Stars)—runs the defile by which the waters of the Chaboras, swollen by the Jaghjagha and other affluents from the Masius, find their way into the heart of Mesopotamia. The Khábúr proper, the ancient Chaboras, which rises in the three-hundred copious fountains of Rás-'ain (the ancient Rhesæna), and ultimately falls into the Euphrates near Karkísiyá (Circesium), forms the boundary between the two, or more correctly the three, great divisions of Mesopotamia. These divisions are (1) the northern country to the west of the Khábúr, (2) the northern country to the east, and (3) the steppe-land. In the country to the north-west of the Khábúr we must probably, as already mentioned, recognize the true ancient *Aram Naharayim*. Under the dominion of the Seleucids it bore the name of Osrhoene, or better Orrhoene, and was for a time the seat of a special dynasty which at a later date at any rate was Arabian (Abgar). The capital of this kingdom was Orfa (Roha), the Edessa of the Greeks and Romans, the Orrhoi of the Syrians; it was at a later date a Roman colony, and bore also the name of Justinopolis. This once flourishing city lies on the small river Daisan (the ancient Scirtus). South of Edessa lie

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[1] Μεσοποταμία, more exactly ἡ μέση τῶν ποταμῶν, scil. χῶρα or Συρία.

[2] In the more recent parts of Genesis Padan Aram takes the place of Aram Naharayim. But this perhaps is the name of a smaller district in the neighbourhood of Harran.

the ruins of Harran (see vol. xi. p. 454). In the Mongolian period Harran fell into decay, and at present it is a mere heap of ruins. A third town of this region is Serug (Gen. xi. 20); in the Greek period it was called Batne, but the Syrians retained the name Serug, which is still in use (Serúj). The town lies between Harran and the Euphrates, in a plain to which it gives its name. On the left bank of the Euphrates lay Apamea (the modern Birejik), connected with Zeugma on the other side by a bridge, and farther south, at the mouth of the Bilechas (modern Belik), was the trading town and fortress Nicephorium, founded by command of Alexander, and completed by Seleucus Nicator, in memory of whose victory it was named. From the emperor Leo it received the designation Leontopolis. The spot is now known as Raḳḳa (see below). Farther up the fruitful valley of the Belik lay the town of Ichnæ (Chne). Farther south lay Circesium (*Chaboras* of Ptolemy, *Phaleg* of Isidor), not to be identified, as is usually assumed, with Carchemish; from the time of Diocletian it was strongly fortified. The site is at present occupied by a wretched place of the name Karkísiyá. Carchemish probably lay near the bridge of Membij, the present Kalat el-Nejm.

In ancient times a highly flourishing district must have stretched along the river Chaboras (Khábúr) to its principal source at Rás-ain ("Fountain-head," Syr. *Rîsh'aina*, the Rhesæna of Ptolemy), a town which was for some time called Theodosiopolis, because after 380 A.D. it was extended and embellished by Theodosius. Justinian fortified it. The strip of completely desert country which now stretches along the lower course of the Khábúr was called in antiquity Gauzanitis, and corresponds to the Gozan of 2 Kings xviii. 6 (Guzana or Guzanu in the cuneiform inscriptions).

The country to the east of the upper Khábúr is in many respects similar to that which has just been described. As the watershed of the Tigris is not far distant, the Masius range sends down into Mesopotamia only insignificant streams, the most important being the Hermas, the Mygdonius of the Greeks. On its banks was situated Nisibis, the chief city of the district, which commanded the great road at the foot of the mountains leading through the steppe, which here from the scarcity of water comes close up to the edge of the hills. In the old Assyrian empire Nasibina was the seat of one of the four great administrative officials. In the time of the Seleucids the site was occupied by the flourishing Greek colony of Antiochia Mygdonia; but the new designation, transferred to the river and the vicinity of Nisibis from the Macedonian district of Mygdonia, afterwards passed out of use. Nisibis was an important trading city, and played a great part in the wars of the Romans against the Persians. Captured by Lucullus, surrendered by Tigranes, recovered by Trajan, again abandoned by Hadrian, once more occupied under Lucius Verus, and strongly fortified by Severus, it was at length raised to be the capital of the province, and remained the frontier fortress of the Romans till in the time of Jovian it was ceded to the Persians. After the loss of Nisibis the emperor Anastasius in 507 founded to the north-west the fortress of Daræ or Daras (the modern Dárá), also called Anastasiopolis, which from the reign of Justinian, who increased its strength, remained for a time the residence of the *dux Mesopotamiæ*. Besides these strongholds, many fortified posts were established by the Byzantine empire in this district. Antoninopolis must be mentioned as an important town; this was refortified by Constantine under the name of Constantia, and has left its ruins near Tela between Harran and Nisibis. Mardin too was a fortress of a similar kind, and the town of Singara, at the southern foot of the mountain of the same name, was an advanced post of the Roman power.

The south or steppe portion of Mesopotamia was from early times the roaming-ground of Arabic tribes; for Xenophon gives the name of Arabia to the district on the left bank of the Euphrates to the west of the Khábúr; and elsewhere it is frequently stated that the interior at a distance from the rivers was a steppe inhabited by Arabes Scenitæ (Tent Arabs). Along the bank of the two great rivers ran a belt of cultivated country, and the rocky islands of the Euphrates were also occupied by a settled population. On the Euphrates, beginning towards the north, we must mention first Zaitah or Zautha, south-east of Circesium; next Corsothe, at the mouth of the Mascash; then Anatho or Anathan, the modern Ana; and finally Is (Hít). On the Tigris the point of most importance is Carnæ (Καιναί of the *Anabasis*), south from the mouth of the Great Zab near the present Ḳal'at Sherḳát; and not far distant towards the interior was Atræ or Hatræ, also called Hatra, the chief town of the Arab tribe of the Atreni. It was besieged without success by Trajan and Severus; by the 4th century it was already destroyed; but the interesting ruins, which can scarcely be visited owing to the plundering habits of the Bedouins, still bear the name of El-Ḥadhr. They lie in the heart of the steppe, and were formerly well supplied with water.

All these districts came in 640 A.D., or perhaps a little earlier, into the power of the Arabs, who named them Jezíra (island) or Jezíret Aḳúr,[1] and divided them according to tribes into three portions, the land of Bekr, of Rebí'a, and of Modhar. The district of Modhar ran along the side of the Euphrates, and its chief towns were Orfa and Raḳḳa; the district of Rebí'a comprised the plain of Mosul as far as the country on the Khábúr (chief towns Mosul and Nisibis), and the district of Bekr (Diyár Bekr) the more mountainous country to the west of the upper Tigris (chief town Amid or Diarbekr). In general the Arabs consider a part of the mountain territories which lie between the two rivers to belong to Jezíra, as is best seen from the following notice given by Abulfeda:—

"El-Jezíra is the land between the Tigris and the Euphrates, yet many places on the other side of the Euphrates, which properly belong to Syria, are also included, as well as places and even districts on the east side of the Tigris. The exact boundary line thus runs from Malatia by Sumeisát, Ḳal'at er-Rúm (Rum-Kala of the maps), and Bire (Birejik) to the point opposite Membij, and then by Bális, Er-Rakka, Karkísiyá, Er-Rahaba (on right bank), and Hít to Anbár. Here the Euphrates ceases to form the boundary, which runs across to the Tigris in the direction of Tekrít, and ascends the Tigris as far as Es-Sinn (Senna) to El-Ḥadítha and Mosul, thence to Jezíret ibn 'Omar, then to Diarbekr, and so back to Malatia."

From the Arabic geographers and travellers we gain the impression that a great part of Mesopotamia, with the exception of the southern steppe of course, must at that time have been in a very flourishing condition; the neighbourhood of Nisibis especially is celebrated as a very paradise. In fact it is only since the Turkish conquest of the country under Sultan Selim in 1515 that it has turned into a desert and gradually lost its fertility. As the nomadic Arabs have continually extended their encroachments, agriculture has been forced to withdraw into the mountains; and this is especially true of the western portions of Mesopotamia, the district of Rás-ain, and the plain of Harran and Serúj, where huge mounds give evidence that the whole country was once covered with towns and villages. Under the Turks El-Jezíra does not form a political unity, but belongs to different pashaliks.

From this brief survey it appears that Mesopotamia, like Syria, constitutes an intermediate territory between the great eastern and western monarchies,—Syria inclining

[1] Philostratus (*c.* 200 A.D.) already reports that the Arabs called Mesopotamia νῆσος.

more to the west, and Mesopotamia to the east. In virtue of its position it frequently formed both the object and the scene of contest between the armies of those mighty monarchies, and it is wonderful how a country so often devastated almost always recovered. The roads, it is true, which traversed the territory were not mere military highways, but the main routes of traffic for Central Asia, Western Asia, and Europe. It is only in modern times, and since these lines of commercial intercourse have ceased to be followed, that the general condition of things has been so entirely altered.

The number of roads which in ancient times traversed the country was very considerable; the Euphrates formed not a barrier but a bond between the nations on either side; at many places there were at least boat-bridges (zeugma) across. One of the most important of the ancient crossing-places must be sought, where in fact it still exists, at Birejik, the ancient Apamea-Zeugma. From this point a great road led across to Edessa (Orfa); there it divided into two branches, the northern going by Amid (Diarbekr) and the other by Mardin and Nisibis to Mosul (Nineveh). In quite recent times, in order to avoid the direct route across the desert and through the midst of the Bedouins, the post-road makes a great circuit from Nisibis by Jezíret ibn ʿOmar to Mosul. A second route crossed the Euphrates somewhat more to the south, and joined the other *via* Harran and Rhesæna. The principal crossing of the earlier times (Xenophon) was at Thapsacus, almost opposite Rakka; and it will be remembered also how important a part Thapsacus (Tiphsah) plays in the Old Testament. Sometimes a route along the Euphrates to Babylonia was followed, as is still frequently done by caravans at the present day; but even in ancient times this course was attended by more or less difficulty, the country being occupied by the chiefs of independent Arab tribes, with whom the travellers had to come to terms.

The ancient condition of things must consequently be considered as essentially analogous to that of the present day; the central districts away from the rivers were occupied at certain seasons, according as they yielded pasture, by nomadic cattle-grazing tribes, the physical character of the country being then and now the same on the whole as that of the Syrian desert, which belongs not to Syria but properly to Arabia. On the banks of the rivers were settled half-nomadic Arab tribes,—tribes, that is, which were more or less on the way to the agricultural stage, or which, having become altogether agricultural, had nevertheless, owing to frequent intercourse with the Bedouins, lost little of their original character, and even maintained their independence. The same movement takes place over and over again: Arab tribes migrating from Arabia, that *officina gentium*, gradually settle down wherever circumstances prove favourable, and by this very change in their mode of life make their first step towards civilization. In this way a continual stream of Arabs has flowed into the civilized countries of Mesopotamia. On the Assyrian monuments are figures of Arabs riding on camels; evidently the Assyrians had carried on war against the Bedouins settled in their territory. At an early period the Ṭai Arabs were the neighbours of the Aramæans, and consequently all Arabs bear in Syriac the name of Tayóyé. The district between Mosul and Nisibis received the name Béth ʿArbáyé from its being occupied by Arabs. These Ṭai Arabs, whose original home was Central Arabia, are still settled partly near Nisibis and partly east of Mosul; but they have to some extent lost their old noble Bedouin manners. The wandering Arab tribe which at the present time is dominant in Mesopotamia is the Shammar; they have driven back the Aneze, the most powerful tribe of the Syrian desert. It is only two or three generations ago that the Shammar came from Nejd; but they have already broken up into two great parties. The head of the one division is Ferhán, who has more or less completely submitted to the Turks, and has consequently obtained the title of pasha; to him adhere the Shammar tribes between Mosul and Baghdad, and those also to the east of the Tigris. The head of the tribes who roam over the greater part of Mesopotamia—pasturing their camels and sheep to the east of the Chaboras in the colder season and to the north in the hotter—is the chivalrous Fáris. These western tribes are totally independent of the Turkish Government, and have offered determined opposition to the attempts of the authorities at Dér to force them to a settled way of life; they still lay the peasants of Mesopotámia under contribution by exacting Khuwwe, "brother-money," or a portion of grain. The Shammar live in almost perpetual feud with their relations to the east, and especially with the Aneze on the Syrian bank of the Euphrates, the so-called Shámiye. Many other Bedouin tribes might here be mentioned; but it may be enough to name the Delém on the Euphrates as an example of a tribe just in process of becoming agricultural. In the northern parts of Mesopotamia there are a number of tribes of mingled Kurds and Arabs which have to a greater or less degree abandoned their tents for fixed habitations and the tillage of the ground; such are the Beraziye near Orfa, the Milliye between Orfa and Mardin, and the Kíkíye nearer Mardin and also in the neighbourhood of Mosul. It is extremely hard to obtain trustworthy statistical information about the number of the Bedouins; the Shammar may have a total strength of some 3500 tents. In the difficult contests which it has to carry on with those independence-loving tribes, the Turkish Government acts in general on the principle *divide et impera*.

The Kurdish element only appears sporadically in the true Mesopotamian plain; but the Yezidis, who form the population of the Sinjar range, may be referred to this stock. He who encounters the uncanny figure of one of these people will hardly be able to restrain a slight shudder, especially if he remembers the graphic descriptions of the Yezidi robbers in Morier's *Ayesha*. Of the old Aramæan peasantry there are no longer any important remains in the plain, the Aramæans having withdrawn farther into the Kurdish highlands, where, in spite of their wild Kurdish neighbours, they are more secure from exactions of every kind. The plain of the northern country of the two rivers was at one time richly cultivated, and owed its prosperity to this industrious people, who formerly played so distinguished a part as a connecting link between the Persians and the Roman empire and afterwards between the Western and the Arabian world, and whose highest culture was developed in this very region. Quite otherwise is it now. In the plain there are almost no remains of the common Aramæan tongue. Apart from the scattered areas in which Kurdish prevails, the ordinary language is a vulgar Arabic dialect; but both Kurdish and Aramæan (Syriac) have exercised an influence on the speech of the Arab peasant. Finally it must be mentioned that certain Turcoman hordes roam about the Mesopotamian territory.

In climate and in the character of its soil, as well as in its ethnographic history, Mesopotamia holds an intermediate position. In this aspect also we must maintain the division into two quite distinct zones. The southern half consists mainly of grey, dreary flats covered with selenite; and gypsum everywhere makes its appearance a little below the surface; bitumen is not unfrequent, and here and there it rises in petroleum wells. In the solid strata of gypsum and marl the rivers have carved out valleys, from a quarter to half a mile broad and from 40 to 50 or even 100 feet deep, which with their arable soil contrast with the barren surface of the more elevated desert (chól). Especially below Bális there are marl-hills capped with gypsum, and alluvial plains (so-called *háwís*) of considerable extent

have been formed. The banks of the rivers are there lined with a luxuriant growth of tamarisks. Occasional swamps and small lagoons occur; and the marl shows a more or less marked efflorescence of salt. In this part of the country frost is rare even in winter; in summer the heat is of extraordinary intensity, and during the whole season from May to the close of October it is but slightly modified by the night-dews. During the sand storms which frequently blow from the West Arabian desert, the temperature may rise to 50° C. (122° Fahr.), and this same excess of heat will then prevail through seven degrees of latitude in the whole valley of the Euphrates and Tigris from the Persian Gulf to the foot of the mountains. For, considering the strong radiation which takes place over what is now the uniform surface of the Mesopotamian soil with its almost complete absence of evaporation, there is nothing to hinder this warm zone extending in summer to the upper half of the country. In winter, on the other hand, this latter region has quite a different climate. From the mild coasts of the Mediterranean the cold increases from west to east. In the spurs of the Taurus, consequently, the winter cold extends far to the south, and the influence of the snow-covered ridges spreads far into the Mesopotamian plain. Snow and ice are thus not unfrequent in the higher part of the plain, and the temperature may fall as low as −10° C. (14° Fahr.), especially if the cold north winds are blowing. That inland region too is cut off from the influence of the mild air of the Mediterranean by the coast ranges. For this reason the vegetation is of a less southern character than that of the Mediterranean countries in the same latitude. In the spring the green is soon parched out of existence. In this way the northern district of Mesopotamia combines strong contrasts, and is a connecting link between the mountain region of western Asia and the desert of Arabia. On the other hand the country to the south of Mesopotamia, or 'Irák, has a warm climate, and towards the Persian Gulf indeed the heat reaches the greatest extremes.

In Upper Mesopotamia, strictly so called, agriculture has suffered an extraordinary decline; in spite of excellent soil, very little of the land is turned to account. In the western district the fertile red-brown humus of the Orfa plain, derived from the lime of Nimrúd Dágh, extends to about 12 miles south of Harran. With a greater rainfall, and an artificial distribution of the water such as existed in olden times, agriculture would flourish. If spring rains are only moderately abundant, wheat and barley grow to a great height, and yield from thirty to forty fold. Rice is also grown in the richly watered hill-encircled district of Serúj and on the banks of the Khábúr. Next, millet and sesamum are the chief crops,—the latter being grown for the sake of its oil, as the olive does not succeed in this region. The abundance of wheat may be estimated from the fact that during Layard's residence in Mosul a camel-load of 480 lb was worth four shillings. Durra (*Holcus Sorghum* and *H. bicolor*), lentils, pease, beans, and vetches are also grown, as well as cotton, safflower, hemp, and tobacco. *Medicago sativa* furnishes fodder for horses. Among the fruits the most noteworthy are the cucumbers, melons, and water-melons planted in great abundance on the banks of the smaller streams. The figs of the Sinjar mountains are celebrated for their exceptional sweetness. Timber trees are few; plane trees and white poplars are planted along the streams, and a kind of willow and a sumach flourish on the banks of the Euphrates. The palm-trees which appear on the banks of both the rivers farther south do not come so far north. On account of the hot dry summer the orange does not succeed. Of the great forest which existed (?) near Nisibis in the time of Trajan no trace remains; but the slopes both of the Masius mountains and of the Jebel 'Abd-el 'Aziz, as well as, more especially, those of the Sinjar range, are still covered with wood.

The wide treeless tracts of the low country of Mesopotamia are covered with the same steppe vegetation which prevails from Central Asia to Algeria, but there is an absence of a great many of the arborescent plants that grow in the rockier and more irregular plateaus of western Asia and especially of Persia. This comparative poverty and monotony of the flora is partly due to the surface being mainly composed of detritus, and partly to the cultivation of the country in remote antiquity having ousted the original vegetation and left behind it what is really only fallow ground untouched for thousands of years. Endless masses of tall weeds, belonging to a few species, cover the face of the country,—large *Cruciferæ*, *Cynareæ*, and *Umbelliferæ* disputing the possession of the soil in company with extraordinary quantities of liquorice (*Glycyrrhiza glabra* and *echinata*) as well as *Lagonychium* and the white ears of the *Imperata*. In autumn the withered weeds are torn up by the wind and driven immense distances. Among the aromatic plants, which even Xenophon mentions in Mesopotamia, the first place belongs to the species of wormwood (*Artemisia*), which cover wide areas, and the second to *Labiatæ*, such as species of thyme and *Salvia*, which, however, become rarer in the low country. With few exceptions there are none but cultivated trees, and these are confined to the irrigated districts on the Euphrates and the Shatt; a few willows, a *Pyrus*, tamarisks, a *Rhus*, a *Rubus*, on the banks of the rivers, and the willow-like *Populus euphratica*, which grows from Dzungaria to Morocco, make up the list of the indigenous kinds. In the wide belt of swamp which lines the Shatt el-'Arab in the low country of 'Irák 'Arabi there are boundless reaches of gigantic sedge inhabited by a rich fauna, especially of birds such as pelicans and flamingoes. From the south, or in other words from the true desert and oasis country of Arabia, the date-palm spreads up the valley to some little distance above Baghdad; and especially along the Shatt it yields rich crops of fruit, which are exported to India. With the exception of a few truffles, capers, liquorice, and such like, there are few wild food-plants. The cycle of vegetation begins in November. The first winter rains clothe the plain with verdure, and by the beginning of the year a number of bulbous plants are in bloom—*Amaryllidæ*, *Liliaceæ*, and *Colchicum*. The full summer development is reached in June; and by the end of August everything is burnt up.

The lion is said to roam as far as the Khábúr; but in any case it is at least much less frequent than in the time of the Assyrians, when the lion-hunt was a recognized form of sport. The wild ass too is very rare; but on the other hand wild swine, hyænas, jackals, cheetahs, and foxes are extremely abundant. Wolves are said to exist in the plain, and among others a variety of black wolf (*Canis lycaon*). Particularly numerous in the steppe are the antelope species; and herds of gazelles are frequently met with. Beavers are said to have been observed on the Euphrates. Jerboas, moles, porcupines, and especially the common European rat, abound in the desert; bats are numerous; and the long-haired desert hare is also found. Among the domestic animals in this steppe country the camel holds the first place; and next come goats and sheep; but the Bedouin sheep is not the ordinary fat-tailed variety. The common buffalo is often kept by the Arabs and Turcomans on the Euphrates and the Tigris; and on the Euphrates we also find the Indian zebu, which is still more frequent in the districts farther to the south. Bird-life is very rare in the southern parts of the plain; though on the Euphrates there are vultures, owls, ravens, &c., as well as falcons (? *Tinnunculus alaudarius*) which are trained to hunt. Among game-birds are some kinds of doves, francolins, partridges, wild ducks and geese, and in the steppe bustards. The ostrich seems almost to have disappeared. Large tortoises are numerous.

In conclusion it is necessary in supplement to the article IRAK to say something of the district of Babylonia, often (though wrongly) included under the name Mesopotamia. Here we have to do with a fundamentally different region, for it consists in the main of alluvial formations, a few scattered reaches of sand only now and then appearing in the level depression not filled up by the alluvium. The mass of solid matter which the rivers bring down and deposit is very considerable; it has been ascertained that the maximum proportion for the Euphrates in the month of January is $\frac{1}{80}$, and at other times $\frac{1}{200}$; for the Tigris the maximum is $\frac{1}{100}$. As regards the physical character of the alluvia, in the most northerly portion the soil is pebbly, the pebbles consisting almost solely of variously coloured flints and occasional small fragments of gypsum. This is succeeded by a continuous formation of clayey soil, in part argillaceous and argillo-calcareous, but covered with mould and sand, or the more tenacious clay of frequent inundations.

In general, the northern plains of the interior have a slight but well-defined southerly inclination with local depressions. The territory undulates in the central districts, and then sinks away into mere marshes and lakes. The clay, of a deep blue colour, abounds with marine shells, and shows a strong efflorescence of natron and sea-salt, the latter derived from the decomposition of vegetable matter. When the soil is parched up the appearance of the mirage (seráb) is very common. As extensive inundations in spring are caused by both the rivers, especially the Tigris, great alterations must have taken place in this part of the country in the course of thousands of years. It has been asserted that in former times the alluvial area at the mouth of the river increased one mile in the space of thirty years; and from this it has been assumed that about the 6th century B.C. the Persian Gulf must have stretched from 45 to 55 miles farther inland than at present. The actual rate of increase at the present time is about 72 feet per annum. For this reason we cannot decide much in regard to the former physical configuration of southern Babylonia; but it is at least certain that the Euphrates and the Tigris reached the sea as independent rivers. Ritter estimates that in the time of Alexander the Great the embouchures were still separated by a good day's journey; and, though they cannot now be traced, great alterations have probably taken place in the upper portions of the rivers as well as in the country near the mouths. Assyriologists tell us that more than thirty-five canals are known by name from the Babylonian period; but it is extremely difficult, or rather it has proved hitherto impossible, to identify them either with those actually existing or with those mentioned in classical authors, in the Babylonian Talmud, or in Arabian writers. To the west of the Euphrates was to be found the Pallacopas channel, and we still have the Hindiye channel in the same quarter. The country between the rivers more particularly was traversed by such secondary branches. Beginning

from the Euphrates we must mention the Saklawíye channel (Nahr 'Isá), the Nahr Melik, the Nahr Zemberáníye, and especially the Nahr-en-Níl, constructed by the famous Omayyad governor Hajjáj. Eastwards from the Tigris strikes the great Nahrawan channel; and right through the country of the two rivers runs the Shatt-el Hai from Kút-el-'Amára, almost due south to the Euphrates, parallel with the Shatt-el-Kehr. Many of these have been silted up; from those, however, which are still maintained there is derived a considerable revenue, and by the restoration of many of the old channels, traces of which are met with at every step, the country might be again raised to that condition of high civilization which it enjoyed not only in antiquity but partly even in the time of the later caliphs. The classical writers are unanimous in their admiration of this country; and it is at least certain that nowhere else in the whole world was the principle of the application of canals to the exigencies of agriculture worked out so successfully. The most luxuriant vegetation was diffused over the whole country; and three crops were obtainable in the year. It is this alone which makes it intelligible how this region in the most remote antiquity attained a high civilization, and for centuries played, it may be said, one of the principal parts in the history of the world. In the matter of civilization, indeed, no country of the ancient world was its equal; a multitude of great cities once flourished within its borders. Even the Arabic writers are unanimous in regard to the extremely favourable influence which the character of the country exercised on the intellectual activity, spirit, and capacity of its inhabitants. We need not here discuss the question recently started as to whether the Biblical garden of Eden is to be sought in this locality, two canals of the Euphrates and Tigris being identified with the Gihon and Pison of Gen. ii.; but it is certain at least that this lower country of the two rivers might well pass in antiquity for the *ne plus ultra* of civilization, and exercised the most powerful political and intellectual influence on the surrounding regions. The question often raised as to whether the Semites were derived from this district may also be left untouched. From the Bible we know that an ancient name of the district was Shinar, though this has not hitherto been discovered in the cuneiform inscriptions. The name Kush is applied in the Bible to its oldest non-Semitic inhabitants. The northern half of the country was called Akkad, the southern Sumer. But it must not be forgotten that the rivers never formed ethnographic and political boundaries; and thus Sumer extended to the coast of the Persian Gulf and Akkad as far as the Lower Zab, the eastern affluent of the Tigris. As a less ancient designation of the whole country may be reckoned *mat Kalda*, the country of the Chaldæans (Hebr., *erets Kasdîm*); originally Kalda is said to have designated central Babylonia. Of still later date is the name derived from the capital, the country of Babel (*erets Bábel*), as an equivalent of which *mât Bâbîlû* appears in the cuneiform inscriptions (in the Darius lists *Babîru*). From this was developed the Greek designation Babylonia, Βαβυλωνία (as early as Xenophon). That the country was densely peopled may be gathered from the fact that about 704 B.C. eighty-nine fortified towns and eight hundred and twenty smaller places in the Chaldæan country were captured during one military expedition. Of separate districts of the country we may mention Karduniash, the district in the vicinity and especially to the north of Babylon; and southward by the sea-coast the important country of Bít Yakín, governed by kings of its own. At a later date we find on the coast and at the mouth of the Pallacopas canal the maritime town of Teredon, which is also mentioned by the classical writers. Besides Babylon and Borsippa, the larger cities were the double city of Sippar (Sefarvayim, 2 Kings xvii. 24, 31) and Akkad on the left bank of the Euphrates on the present Nahr 'Isá; Erech, *i.e.*, Warka, on the left bank of the Euphrates; Ur on the Pallacopas, not far from the place where the Shatt-el-Hai falls into the Tigris; Nippur, *i.e.*, Tell Niffer; Kutha (2 Kings xvii. 24), Kalne (Gen. x. 10), in the north, Opis at the junction of the Adhem (Physcus) with the Tigris. Huge mounds give evidence of the extent of these cities. A number of the canals were navigable, and at the same time, when the bridges were destroyed, they formed defensive moats against the incursion of enemies from the north. And the same purpose was served by the great wall (afterwards the Median Wall of the Greeks) which ran across the country from river to river between the points of their nearest approach.

During the period of Greek domination a Greek city, Seleucia, which afterwards attained great prosperity, was founded by Seleucus I. in an extremely favourable situation on the right bank of the Tigris. In the south of the country, too, there was a Greek seaport town first called Alexandria on the Tigris and afterwards Antiochia. After the conquest of Babylonia by the Parthians (130 B.C.) a small Arabian kingdom grew up in those parts called Characene or Mesene, after the town of Charæ or Maisan. It was under Parthian and for a time under Roman supremacy. The city of Vologesia, founded by Vologeses to the south-west of Babylon, near Ullais, in the neighbourhood of the later Kúfa, was one of the capitals of the Parthian power. In the time of the Sasanids, too, as well as in that of the Parthians, the country of the lower Euphrates and Tigris played a leading part; it formed in fact the main centre of the Persian kingdom. The city of Ctesiphon, founded by the Greeks on the east side of the Tigris opposite Seleucia, was the winter residence of the Parthian kings, and the imperial capital of the Sasanids. Under the name of Madáin (The Cities) it continued to flourish till the rise of Baghdad in the 9th century. The neighbourhood of Ctesiphon was called in the time of the Sasanids Súristán, a translation of the Aramæan designation Bêth-Arâmâyê, "country of the Syrians," for the land was mainly occupied by Aramæans. By a notable substitution the Arabs afterwards gave the name Nabat, *i.e.*, Nabatæans, to these Aramæan peasantry, who, it may be added, were already found in these parts at the time of the Babylonian empire.

On the west side of the Tigris the Arab kingdom of Híra formed the bulwark of the Sasanid power. As the result mainly of the battle of Kadisiya (east of Híra) in 635 A.D., the whole of this wealthy country fell into the hands of the Moslems, and it soon constituted the centre of their power, especially when the Abbasids, with true political insight, transferred thither the capital of the empire and founded Baghdad. The chief cities of the older Arabic period were Kúfa (in the neighbourhood of the earlier Híra to the south of ancient Babylon) and Basra (or BUSSORAH, *q.v.*) in the neighbourhood of the earlier Maisan. After these two cities the country was divided into the Sawád, "rich arable district," of Basra and that of Kúfa. Sawád was also employed as a name for the whole country; and more or less identical with this designation is the name 'Irák still in use. Sometimes also the term Sawád-el-'Irák is employed; but at a later date the country is distinguished as 'Irák 'Arabi (Arabian 'Irák) from the Persian 'Irák 'Ajemi to the east, the ancient Media. The Arabian geographer Yákút makes the distinction that the country called Sawád reaches farther to the north (viz., to the district of the Upper Záb).

Abulfeda gives the boundaries of 'Irák as follows:—"In the west of the country lie El-Jezíra and the desert, in the south the desert, the Persian Gulf, and Khuzistán, in the east the mountain country as far as Holwán (near the principal pass through the Zagrus range). Thence the boundary runs again towards Mesopotamia. Thus the greatest breadth of 'Irák is in the north, and its narrow extremity is formed by the island 'Abbádán in the Shatt-el-'Arab (the united Euphrates and Tigris) to the south of Basra." From what has been said it appears that 'Irák extended far beyond the country between Euphrates and Tigris. Abulfeda says clearly that 'Irák lies on the Tigris as Egypt on the Nile; for according to this view the Tigris flows through the middle of the country. 'Irák consequently lies between 30° and 34° 30′ N. lat. and between 44° and 48° 30′ E. long.; of its area it is impossible to form an estimate under such varying conditions. For some details see BAGHDAD.

From the union of the rivers upwards, in the case of the Euphrates as far as 26° N. lat. (above Rakka), in that of the Tigris to 35° N. lat., the valleys are known as *ez-zór*, the depression, in opposition to the more elevated desert-plateau. It has been surmised that in this name is to be recognized the Dúra of the Old Testament (Daniel iii. 1).

Very little of the ancient condition of the country has been preserved; and there are now but few remains of ancient buildings, scarcity of stone having all along led to the use of bricks. 'Irák has played its part. It is only by the expenditure of immense sums, far beyond the financial capacity of the Turkish Government, that the ancient canals could be restored and the swamps formed by them drained. The whole land falls into two unequal portions,—an extensive dry steppe with at any rate a healthy desert climate, and an unhealthy region of swamps. There is a good deal more agriculture along the Euphrates than along the Tigris; but swamps, with almost impenetrable reed thickets, composed of a kind of *Agrostis*, are at the same time much more extensive. The slightly more elevated districts are the special habitat of the date palm, which by itself forms dense groves bordering the banks particularly on the lower Euphrates, for a distance of several days' journey. This part of the country consequently has a somewhat monotonous but in its own way imposing aspect. A luxuriant vegetation of water-plants is to be found in the swamps, which are the haunt of numerous wild beasts—wild swine, lions, different kinds of aquatic animals and birds. The swamps are inhabited by a wild race of men, dark of hue, with many negroes amongst them. They live in reed huts, and cultivate rice; and they weave straw mats. In the main they keep pretty free both of the Turkish Government and of the semi-Bedouins and Bedouins of 'Irák. The Khazael especially who dwell to the south of ancient Babylon often give the Government trouble, through their passion for independence. Less turbulent are the Bedouins in the interior of the country—the Zobeid, the Afaij, and the Abu Muhammed; but on the other hand the Beni Lám (7500 tents strong), who occupy the great tract of country east of the Tigris to the south of Baghdad, have often been a source of great annoyance to the pashas of that city. A still more difficult task is the management of the Shammar, who come and pitch their tents to the south-east of Baghdad; and also the Muntefitch on the southern Euphrates put the whole ad-

ministrative and diplomatic skill of the Turkish officials to the test. The Turkish influence has here made at one time great advance and at another lost all the ground it had gained,—the rich and powerful sheikhs of the Muntefitch sometimes becoming for a season rulers over the whole of Southern 'Irák and even over the town of Basra. The present writer once visited the great sheikh Násir in his camp near Súk-esh-Shiyúkh; and he received the impression of having to do with a very remarkable and astute personage.

The old Syrian population of 'Irák has almost entirely disappeared; the few remnants left are distinguished by a special religion, in regard to which see the article MANDÆANS. Ethnographically the country is subject to a double influence. On the one hand the connexion with Nejd, the central plateau of Arabia, continues uninterrupted; the emigration from that region being mainly directed towards 'Irák and Jezíra. In Baghdad even, the 'Agél-Bedouins from Central Arabia have a quarter of their own. With the earnings obtained in these rich districts the emigrants return to their homes. But quite as strong at least is the influence of Persia. Persian customs are in fashion; in Baghdad there is an important Persian quarter; and Kerbela and Meshed 'Ali to the west of the Euphrates may be considered regular Persian "enclaves." In these places are buried the son-in-law of Mohammed, the caliph Ali, and his son Hosein (in Kerbela), the chief saints of the Shiite sect; and their tombs are not only shrines of pilgrimage to the living, but the dead are brought by countless caravans from Persia to be buried in ground which they have made holy. The neighbourhood of Kerbela reeks with the odour of corpses; and from the midst of them pestilence has often begun its march. Throughout the whole of 'Irák the Shiites have many adherents,—for example, the Khazael already mentioned. Persian influence prevails on the Arab population of 'Irák, and the intermingling of the races can still be very clearly traced; in this distant corner of the Turkish empire a more international tone prevails than in any other district. And, however small when compared with former times the commercial and intellectual intercourse of various nations in these regions may be at the present day, the attentive observer must notice that such intercourse does still exist, though within restricted limits. No trace, indeed, is to be found of that rich intellectual development which was produced in the time of the caliphs through the reciprocal action of Persian and Arabic elements. Still the quickwittedness of the inhabitants of 'Irák makes a decided impression on the traveller passing through Asiatic Turkey; and one might venture to prophesy that the country might to some extent recover its former position in the world, especially if English influence from India were more widely extended, and should lead to the construction of a railway. The trade which passes through 'Irák is even now not unimportant; horses, for example, are exported in considerable numbers from southern 'Irák to India. But it might be very much improved, as the country, it is said, could support five hundred times as many inhabitants as it actually contains. There is also a considerable export of dates, a fruit which forms the chief sustenance of a great number of the inhabitants; and the breeding of cattle (especially buffaloes) is extensively carried on. Only a few steamboats as yet navigate the majestic rivers. Communication by water is carried on by means of the most primitive craft. Goods are transported in the so-called "terrades," moderately big high-built vessels, which also venture out into the Persian Gulf as far as Kuwét. Passengers are conveyed, especially on the Euphrates, in the *meshhúf*, a very long and narrow boat, mostly pushed along the river bank with poles. The Mesopotamian "kelleks"—rafts laid on goatskin bladders—come down as far as Baghdad, where round boats made of plaited reeds pitched with asphalt are in use. At Basra, on the other hand, we see the "belem," boats of a large size, having the appearance of being hollowed out of tree trunks, and partly in fact so constructed. Throughout 'Irák in general Indian influence is partially at work; in the hot summer months, for instance, when the natives live in underground apartments (serdáb), the Indian punkah is used in the houses of the rich. As regards language, the local Arabic dialect has evidently been affected on the one hand by Persian, on the other by the Bedouin forms of speech.

See Ritter, *Die Erdkunde von Asien*, 2d ed. vol. vii., 10th and 11th parts, Berlin, 1843, 1844; Chesney, *Expedition for the Survey of the Rivers Euphrates and Tigris*, 2 vols., London, 1850; W. Ainsworth, *Researches in Assyria, Babylonia, and Chaldæa*, London, 1838; Fr. Delitzsch. *Wo lag das Paradies?* Leipsic, 1881. Map: Kiepert, *Die Euphrat- und Tigrisländer*, Berlin, 1854. (A. SO.)

MESSENE, the chief city of Messenia, founded, under the auspices of Epaminondas, as a bulwark against the Spartans. After the battle of Leuctra that general sent to all the exiled Messenians,—in Africa, Sicily, or Italy,—and invited them to return to the land of their fathers. Many came with eagerness, and in 369 B.C. the city was built by the combined army of Thebans under Epaminondas and Argives under Epiteles, assisted by the Messenians themselves. The site was chosen in conformity with a vision which appeared to Epaminondas, and the walls were raised to the sound of flutes playing the airs of Sacadas and Pronomus. The citadel was erected on the summit of Mount Ithome, and the city on its southern slope and in the adjoining valley. City and citadel were enclosed by a wall 47 stadia in length. Near the centre of the city was the agora, with a famous spring called Arsinoe, and various temples and statues, among the latter an iron statue of Epaminondas. The Hierothysion contained many statues of gods and heroes, among them a bronze statue of Epaminondas. In the gymnasium were statues of Hermes, Hercules, and Theseus by Egyptian artists. In the stadium was a bronze statue of the great hero Aristomenes, who had a sepulchral monument elsewhere in the city. On the summit of the citadel was a famous spring called Clepsydra, and near it a temple of Zeus Ithomatas, with a statue by the famous Argive artist Ageladas, executed originally for the Messenian Helots who settled in Naupactus (see MESSENIA). It was in honour of this statue that the festival of the Ithomæa was performed.

The situation of Messene is one of the finest and most romantic in the world. The view of Mount Ithome, with its level summit and its ancient and mediæval ruins, as one issues from the Langadha Pass in the Taygetus mountains, is beautiful beyond description. And the view from the summit of the mountain itself, which rises, steep and rugged, to the height of 2631 feet, and is crowned by the ruins of fortifications of Cyclopean workmanship, is enchanting, hardly equalled by any other in Greece. Near the middle of the ruins of the lower city stands a wretched village named Mavrommáti (Black Eye), so called from the Turkish name of the spring Arsinoe, which still flows as plentifully as in the old days. These ruins are the most imposing in Greece, and furnish the finest existing specimen of Hellenic military architecture. Almost the entire circuit of the ancient walls can be traced, and in some places they are standing to their full height. They are built of large hewn stones laid in beautifully regular layers without mortar, and are surmounted by towers, of which there seem to have been originally over thirty. Seven of these are still in a good state of preservation, and bear testimony to the thoroughness of the great enterprise undertaken by Epaminondas. Two gates can still be distinguished, one on the slope of Mount Ithome, the other (the northern or Megalopolis gate) on the north side. The latter is a dipylon or double gate, opening into a circular enclosure 62 feet in diameter. The walls of this enclosure are built with extreme care, and the soffit stone of the inner portal, which has been partly moved from its place, reminds one of the lintel of the so-called treasury of Atreus at Mycenæ. It is 18 ft. 8 in. × 4 ft. 2 in. × 2 ft. 10 in. Within the town several ancient sites can still be distinguished—the stadium, the theatre, and several temples.

MESSENIA (in Homer Messene), a state of Greece, and the most westerly of the three peninsulas of the Peloponnesus. Its area is a little over 1160 square miles. It is separated from Elis and Arcadia on the north by the river Neda and the Nomian mountains, and from Laconia on the east by the lofty range of Taygetus. The other sides are washed by the sea, which indents its shores with four gulfs or bays,—Messenia, Phœnicus, Pylus, and Cyparissus. On its south-west corner are the Œnussæ Islands, and opposite the bay of Pylus (Navarino) the famous Sphacteria. The interior is divided by mountain chains into fertile plains, watered by rivers, the chief of which is the Pamisus (with its tributaries Leucasia, Charadrus, Amphitus, and Aris), falling into the Messenian Gulf. The great valley

of this river is divided, near Mount Ithome, into two distinct parts, the plain or basin of Stenyclarus on the north, and the plain of Macaria, so called from its extreme fertility, on the south. The climate is delightful.

The earliest inhabitants of Messenia were Leleges, whose capital was at Andania. After these came Ætolians, whose chief centre was at Pylus. After the Dorian conquest the country was divided by Cresphontes into five parts, whose chief cities were respectively Stenyclarus, Pylus, Rhion, Hyamia, and Mesola. The towns of Messenia were not numerous. Homer mentions Pylus (the seat of the Thessalian Neleids), Amphigeneia (possibly the same as Ampheia), Dorion, Æpeia (possibly Methone), Œchalia, Pharæ, Antheia (probably the later Thuria), Pedasus, and Ira (the later Abia). Other important towns were Asine, Corone, Limnæ, Carnasium, Cyparissia, and, finally, Messene.

Of the history of Messenia before the Dorian invasion little is known except a few fables related by Pausanias. Two generations after the Trojan war, the country was invaded by the Dorians, who expelled the Neleids and conferred the sovereignty upon Cresphontes, who seems to have been a popular king. Perhaps for this reason he was put to death by the chiefs along with all his sons except Æpytus. Æpytus was restored to the throne by the Arcadians, took vengeance for his father's death, and became very popular. His line lasted through several generations. We know little of the subsequent history of Messenia until the date of the Messenian wars, waged against Sparta. The ostensible and immediate causes of these wars are variously assigned; but the true cause was the cupidity of Sparta. Our chief trustworthy authority for the history of them is the old elegiac poet Tyrtæus; but so little is known about them that it is a matter of doubt in which of them the great hero Aristomenes won his fame. The date of the first was from 743 to 724, of the second from 685 to 668 or, according to others, from 648 to 631 B.C. Ithome was the centre of action in the first, Eira in the second. The result of these wars was the complete subjugation of Messenia to Sparta. Its territory was parcelled out among Spartans, and its towns handed over to Periœci and Helots. Many of the inhabitants took refuge in Arcadia, but still more in Italy and Sicily. A very large number settled in Rhegium, whose chiefs for many generations were of Messenian stock. About 200,000 remained behind in bondage. After the second war a large number of Messenians settled on the Sicilian coast at Zancle, to which they subsequently gave the name Messana (see MESSINA). In 464 B.C. the Messenian Helots, taking advantage of an earthquake at Sparta, revolted, and, though they were finally compelled to surrender in 455, they did so only on condition of being allowed to retire to Naupactus on the Corinthian Gulf. This city had been offered them as a residence by the Athenians, ever glad to favour the foes of Sparta. Here the Messenians remained for sixty years, until the loss of the battle of Ægospotami deprived them of the protection of the Athenians. They were then driven out, and had to find homes in Cephallenia and Zacynthus, or among their kinsmen in Rhegium and Messana. Some even went to Africa, and took up their abode at Euesperidæ or Hesperidæ, afterwards called Berenice. Things remained in this condition until 369 B.C., when Epaminondas, having broken the power of Sparta, rent from her Messenia, and, collecting from all quarters the descendants of the exiled inhabitants, helped them to found the city of MESSENE (*q.v.*). Sparta never gave up her claim to Messenia, and made many attempts to reconquer it, but without success. The Messenians maintained their independence until 146 B.C., when, with the Achæans, they were reduced under the power of Rome. From that time they fall into the background of history. In the Middle Ages the country, like the rest of the Peloponnesus, was largely overrun by Slavic tribes, as is shown by the numerous Slavic local names occurring in it. At the establishment of Greece as a kingdom, Messenia was constituted into a province, with a governor or nomarch residing at Kalamata (officially Kalamai), the ancient Pharæ. The country, though beautiful and fertile, is still in a deplorably backward condition, and the population is sparse and semi-barbarous. Agriculture languishes, and the roads and bridges are few and bad. More deeds of violence occur in Messenia than in any other part of Greece. With the exception of Kalamata, it contains no town of importance. Navarino, on the Gulf of Pylus, was the scene of the destruction of the Turkish fleet in 1827.

MESSIAH (Dan. x. 25, 26), MESSIAS (John i. 41; iv. 25), are transcriptions (the first form modified by reference to the etymology) of the Greek Μεσσίας (Μεσίας, Μεσσείας), which in turn represents the Aramaic מְשִׁיחָא (*mĕshîḥâ*), answering to the Hebrew הַמָּשִׁיחַ, "the anointed."[1] The Hebrew word with the article prefixed occurs in the Old Testament only in the phrase "the anointed priest" (Lev. iv. 3, 5, 16; vi. 22 [15]), but "Jehovah's anointed" is a common title of the king of Israel, applied in the historical books to Saul and David, in Lam. iv. 20 to Zedekiah, and in Isa. xlv. 1 extended to Cyrus. In the Psalms corresponding phrases (My, Thy, His anointed)[2] occur nine times, to which may be added the lyrical passages 1 Sam. ii. 10, Hab. iii. 13. In the intention of the writers of these hymns there can generally be no doubt that it refers to the king then on the throne, or, in hymns of more general and timeless character, to the Davidic king as such (without personal reference to one king);[3] but in the Psalms the ideal aspect of the kingship, its religious importance as the expression and organ of Jehovah's sovereignty, is prominent. When the Psalter became a liturgical book the historical kingship had gone by, and the idea alone remained, no longer as the interpretation of a present political fact, but as part of Israel's religious inheritance. It was impossible, however, to think that a true idea had become obsolete merely because it found no expression on earth for the time being; Israel looked again for an anointed king to whom the words of the sacred hymns should apply with a force never realized in the imperfect kingship of the past. Thus the psalms, especially such psalms as the second, were necessarily viewed as prophetic; and meantime, in accordance with the common Hebrew representation of ideal things as existing in heaven, the true king remains hidden with God. The steps by which this result was reached must, however, be considered in detail.

The hope of the advent of an ideal king was only one feature of that larger hope of the salvation of Israel from all evils, the realization of perfect reconciliation with Jehovah, and the felicity of the righteous in Him, in a new order of things free from the assaults of hostile nations and the troubling of the wicked within the Hebrew community, which was constantly held forth by all the prophets, from the time when the great seers of the 8th century B.C. first proclaimed that the true conception of Jehovah's relation to His people was altogether different from what was realized, or even aimed at, by the recognized civil and religious leaders of the two Hebrew kingdoms, and that it could become a practical reality only through a great deliverance following a sifting judgment of the most terrible kind. The idea of a judgment so severe as to render possible an entire breach with the guilty past, and of a subsequent complete realization of Jehovah's kingship in a regenerate nation, is common to all the prophets, but is expressed in a great variety of forms and images, conditioned by the present situation and needs of Israel at the time when each prophet spoke. As a rule the prophets directly connect the final restoration with the removal of the sins of their own age, and with the accomplishment of such a work of judgment as lies within their own horizon; to Isaiah the last troubles are those of Assyrian invasion, to Jeremiah the restoration follows on the exile to Babylon; Daniel connects the future glory with the overthrow of the Greek monarchy. The details of the prophetic pictures show a corresponding variation; but all agree in giving the central place to the realization of a real effective kingship of Jehovah; in fact the conception of the religious subject

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[1] The transcription is as in Γεσσούρ, Γεσσίρ for גְּשׁוּר, *Onomastica*, ed. Lag., pp. 247, 281, Βασ. β ii. 3. For the termination *ας* for חא, see Lagarde, *Psalt. Memph.*, p. VII.

[2] The plural is found in Psalm cv. 15, of the patriarchs as consecrated persons.

[3] In Ps. lxxxiv. 9 [10] it is disputed whether the anointed one is the king, the priest, or the nation as a whole. The second view is perhaps the best.

moulded that hope into certain fixed forms which were taken with a literalness not contemplated by the prophets themselves. It was, however, only very gradually that the figure and name of the Messiah acquired the prominence which they have in later Jewish doctrine of the last things and in the official exegesis of the Targums. In the very developed eschatology of Daniel they are, as we have seen, altogether wanting, and in the Apocrypha, both before and after the Maccabee revival, the everlasting throne of David's house is a mere historical reminiscence (Sirach xlvii. 11; 1 Mac. ii. 57). So long as the wars of independence worthily occupied the energies of the Palestinian Jews, and the Hasmonæan sovereignty promised a measure of independence and felicity under the law, in which the people were ready to acquiesce, at least, till the rise of a new prophet (1 Mac. xiv. 41), the hope that connected itself with the house of David was not likely to rise to fresh life, especially as a considerable proportion of the not very numerous passages of Scripture which speak of the ideal king might with a little straining be applied to the rising star of the new dynasty (comp. the language of 1 Mac. xiv. 4–15). It is only in Alexandria, where the Jews were still subject to the yoke of the Gentile, that at this time (*c.* 140 B.C.) we find the oldest Sibylline verses (iii. 652 *sq.*) proclaiming the approach of the righteous king whom God shall raise up from the East (Isa. xli. 2) to establish peace on earth and inaugurate the sovereignty of the prophets in a regenerate world. The name Messiah is still lacking, and the central point of the prophecy is not the reign of the deliverer but the subjection of all nations to the law and the temple.[1]

With the growing weakness and corruption of the Hasmonæan princes, and the alienation of a large part of the nation from their cause, the hope of a better kingship begins to appear in Judæa also; at first darkly shadowed forth in the *Book of Enoch* (chap. xc.), where the white steer, the future leader of God's herd after the deliverance from the heathen, stands in a certain contrast to the inadequate sovereignty of the actual dynasty (the horned lambs); and then much more clearly, and for the first time with use of the name Messiah, in the *Psalter of Solomon*, the chief document of the protest of Pharisaism against its enemies the later Hasmonæans. The struggle between the Pharisees and Sadducees, between the party of the scribes and the party of the Hasmonæan aristocracy, has been described in ISRAEL (vol. xiii. p. 423 *sq.*). It was a struggle for mastery between a secularized hierarchy on the one hand, to whom the theocracy was only a name, and whose whole interests were those of their own selfish politics, and on the other hand a party to which God and the law were all in all, and whose influence depended on the maintenance of the doctrine that the exact fulfilling of the law according to the precepts of the scribes was the absorbing vocation of Israel. This doctrine had grown up in the political nullity of Judæa under Persian and Grecian rule, and no government that possessed or aimed at political independence could possibly show constant deference to the punctilios of the schoolmen. The Pharisees themselves could not but see that their principles were politically impotent; the most scrupulous observance of the Sabbath, for example—and this was the culminating point of legality—could not thrust back the arms of the heathen. Thus the party of the scribes, when they came into conflict with an active political power, which at the same time claimed to represent the theocratic interests of Israel, were compelled to lay fresh stress on the doctrine that the true deliverance of Israel must come from God and not from man. We have seen indeed that the legalism which accepted Jehovah as legislator, while admitting that his executive sovereignty as judge and captain of Israel was for the time dormant, would from the first have been a self-destructive position without the complementary hope of a future vindication of divine justice and mercy, when the God of Israel should return to reign over his people for ever. Before the Maccabee revival the spirit of nationality was so dead that this hope lay in the background; the ethical and devotional aspects of religion under the law held the first place, and the monotony of political servitude gave little occasion for the observation that a true national life requires a personal leader as well as a written law. But now the Jews were a nation once more, and national ideas came to the front. In the Hasmonæan sovereignty these ideas took a political form, and the result was the secularization of the kingdom of God for the sake of a harsh and rapacious aristocracy. The nation threw itself on the side of the Pharisees; but it did so in no mere spirit of punctilious legalism, but with the ardour of a national enthusiasm deceived in its dearest hopes, and turning for help from the delusive kingship of the Hasmonæans to the true kingship of Jehovah, and to His vicegerent the king of David's house. It is in this connexion that the doctrine and name of the Messiah appear in the *Psalter of Solomon*. The eternal kingship of the house of David, so long forgotten, is seized on as the proof that the Hasmonæans have no divine right.

"Thou, Lord, art our king for ever and ever. . . . Thou didst choose David as king over Israel, and swarest unto him concerning his seed for ever that his kingship should never fail before Thee. And for our sins sinners (the Hasmonæans) have risen up over us, taking with force the kingdom which Thou didst not promise to them, profaning the throne of David in their pride. But Thou, O Lord, will cast them down and root out their seed from the land, when a man not of our race (Pompey) rises up against them. . . . Behold, O Lord, and raise up their king the Son of David at the time that Thou hast appointed, to reign over Israel Thy servant; and gird him with strength to crush unjust rulers; to cleanse Jerusalem from the heathen that tread it under foot, to cast out sinners from Thy inheritance; to break the pride of sinners and all their strength as potter's vessels with a rod of iron (Ps. ii. 9); to destroy the lawless nations with the word of his mouth (Isa. xi. 4); to gather a holy nation and lead them in righteousness. . . . He shall divide them by tribes in the land, and no stranger and foreigner shall dwell with them; he shall judge the nations in wisdom and righteousness. The heathen nations shall serve under his yoke; he shall glorify the Lord before all the earth, and cleanse Jerusalem in holiness as in the beginning. From the ends of the earth all nations shall come to see his glory and bring the weary sons of Zion as gifts (Isa. lx. 3 *sq.*); to see the glory of the Lord with which God hath crowned him, for he is over them a righteous king taught of God. In his days there shall be no unrighteousness in their midst; for they are all holy, and their king the anointed of the Lord (χριστὸς κύριος, mistranslation of משיח יהוה). He shall not trust on horses and riders and bowmen, nor heap up gold and silver for war, nor put his confidence in a multitude for the day of war. 'The Lord is king,' that is his hope. . . . He is pure from sin to rule a great people, to rebuke governors and destroy sinners by his mighty word. In all his days he is free from offence against his God, for He hath made him strong by the Holy Spirit. . . . His hope is in the Lord; who can do aught against him? Strong in deeds and mighty in the fear of the Lord, he feedeth the flock of the Lord in truth and righteousness, and suffereth not one of them to stumble in the pasture. . . . So it beseemeth the king of Israel whom God hath chosen to lead the house of Israel. . . . God hasten His mercy on Israel to deliver them from the uncleanness of profane foes. The Lord is our king for ever and ever."—*Psalt. Sol.* xvii.

This conception is traced in lines too firm to be those of a first essay; it had doubtless grown up as an integral part of the religious protest against the Hasmonæans. And while the polemical motive is obvious, and the argument from prophecy against the legitimacy of a non-Davidic dynasty is quite in the manner of the scribes, the spirit of theocratic fervour which inspires the picture of the Messiah is broader and deeper than their narrow legalism. In a word, the Jewish doctrine of the Messiah marks the fusion of Pharisaism with the national religious feeling of the

[1] In *Sibyll.*, iii. 775, νηόν must undoubtedly be read for υἱόν.

Maccabee revival. It is this national feeling that, claiming a leader against the Romans as well as deliverance from the Sadducee aristocracy, again sets the idea of the kingship rather than that of resurrection and individual retribution in the central place which it had lost since the captivity. Henceforward the doctrine of the Messiah is at once the centre of popular hope and the object of theological culture. The New Testament is the best evidence of its influence on the masses (see especially Matt. xxi. 9); and the exegesis of the Targums, which in its beginnings doubtless reaches back before the time of Christ, shows how it was fostered by the Rabbins and preached in the synagogues.[1] Its diffusion far beyond Palestine, and in circles least accessible to such ideas, is proved by the fact that Philo himself (*De Præm. et Pœn.*, § 16) gives a Messianic interpretation of Num. xxiv. 27 (LXX.). It must not indeed be supposed that the doctrine was as yet the undisputed part of Hebrew faith which it became when the fall of the state and the antithesis to Christianity threw all Jewish thought into the lines of the Pharisees. It has, for example, no place in the *Assumptio Mosis* or the *Book of Jubilees*. But, as the fatal struggle with Rome became more and more imminent, the eschatological hopes which increasingly absorbed the Hebrew mind all group themselves round the person of the Messiah. In the later parts of the *Book of Enoch* (the "symbols" of chaps. xlv. *sq.*) the judgment day of the Messiah (identified with Daniel's "Son of Man") stands in the forefront of the eschatological picture. Josephus (*B. J.* vi. 5, § 4) testifies that the belief in the immediate appearance of the Messianic king gave the chief impulse to the war that ended in the destruction of the Jewish state; after the fall of the temple the last apocalypses (*Baruch*, 4 *Ezra*) still loudly proclaim the near victory of the God-sent king; and Bar Cochebas, the leader of the revolt against Hadrian, was actually greeted as the Messiah by Rabbi Akiba (comp. Luke xxi. 8). These hopes were again quenched in blood; the political idea of the Messiah, the restorer of the Jewish state, still finds utterance in the daily prayer of every Jew (the *Sh'mônê Esrê*), and is enshrined in the system of Rabbinical theology; but its historical significance was buried in the ruins of Jerusalem.[2]

But the proof written in fire and blood on the fair face of Palestine that the true kingdom of God could not be realized in the forms of an earthly state, and under the limitations of national particularism, was not the final refutation of the hope of the Old Testament. Amidst the last convulsions of political Judaism a new and spiritual conception of the kingdom of God, of salvation, and of the Saviour of God's anointing, had shaped itself through the preaching, the death, and the resurrection of Jesus of Nazareth. As applied to Jesus the name of Messiah lost all its political and national significance, for His victory over the world, whereby He approved himself the true captain of salvation, was consummated, not amidst the flash of earthly swords or the lurid glare of the lightnings of Elias, but in the atoning death through which He entered into the heavenly glory. Between the Messiah of the Jews and the Son of Man who came not to be ministered to but to minister, and to give his life a ransom for many, there was on the surface little resemblance; and from their standpoint the Pharisees reasoned not amiss that the marks of the Messiah were conspicuously absent from this Christ. But when we look at the deeper side of the Messianic conception in the *Psalter of Solomon*, at the heartfelt longing for a leader in the way of righteousness and acceptance with God which underlies the aspirations after political deliverance, we see that it was in no mere spirit of accommodation to prevailing language that Jesus did not disdain the name in which all the hopes of the Old Testament were gathered up. The kingdom of God is the centre of all spiritual faith, and the perception that that kingdom can never be realized without a personal centre, a representative of God with man and man with God, was the thought, reaching far beyond the narrow range of Pharisaic legalism, which was the last lesson of the vicissitudes of the Old Testament dispensation, the spiritual truth that lay beneath that last movement of Judaism which concentrated the hope of Israel in the person of the anointed of Jehovah.

It would carry us too far to consider in this place the details of the Jewish conception of the Messiah and the Messianic times as they appear in the later apocalypses or in Rabbinical theology. See for the former the excellent summary of Schürer, *NTliche Zeitgeschichte*, §§ 28, 29 (Leipsic, 1874), and for the latter, besides the older books catalogued by Schürer (of which Schoettgen, *Horæ*, 1742, and Bertholdt, *Christologia Judæorum*, 1811, may be specially named), Weber, *Altsynagogale Theologie* (Leipsic, 1880). For the whole subject see also Drummond, *The Jewish Messiah* (London, 1877), and Kuenen, *Religion of Israel*, chap. xii. For the Messianic hopes of the Pharisees and the *Psalter of Solomon* see especially Wellhausen, *Pharisäer und Sadducäer* (Greifswald, 1874). In its ultimate form the Messianic hope of the Jews is the centre of the whole eschatology, embracing the doctrine of the last troubles of Israel (called by the Rabbins the "birth pangs of the Messiah"), the appearing of the anointed king, the annihilation of the hostile enemy, the return of the dispersed of Israel, the glory and world-sovereignty of the elect, the new world, the resurrection of the dead, and the last judgment. But even the final form of Jewish theology shows much vacillation as to these details, especially as regards their sequence and mutual relation, thus betraying the inadequacy of the harmonistic method by which they were derived from the Old Testament and the stormy excitement in which the Messianic idea was developed. It is, for example, an open question among the Rabbins whether the days of the Messiah belong to the old or to the new world (הָעוֹלָם הַזֶּה or הָעוֹלָם הַבָּא), whether the resurrection embraces all men or only the righteous, whether it precedes or follows the Messianic age. Compare MILLENNIUM.

We must also pass over the very important questions that arise as to the gradual extrication of the New Testament idea of the Christ from the elements of Jewish political doctrine which had so strong a hold of many of the first disciples—the relation, for example, of the New Testament Apocalypse to contemporary Jewish thought. A word, however, is necessary as to the Rabbinical doctrine of the Messiah who suffers and dies for Israel, the Messiah son of Joseph or son of Ephraim, who in Jewish theology is distinguished from and subordinate to the victorious son of David. The developed form of this idea is almost certainly a product of the polemic with Christianity, in which the Rabbins were hard pressed by arguments from passages (especially Isa. liii.) which their own exegesis admitted to be Messianic, though it did not accept the Christian inferences as to the atoning death of the Messianic king. That the Jews in the time of Christ believed in a suffering and atoning Messiah is, to say the least, unproved and highly improbable. See, besides the books above cited, De Wette, *Opuscula*; Wünsche, *Die Leiden des Messias*, 1870. The opposite argument of King, *The Yalkut on Zechariah* (Cambridge, 1882), App. A, does not really prove more than that the doctrine of the Messiah Ben Joseph found points of attachment in older thought. (W. R. S.)

MESSINA, a city and seaport at the north-east corner of Sicily, capital of the province of the same name,[3] is

[1] The Targumic passages that speak of the Messiah are registered by Buxtorf, *Lex. Chald.*, s.v.

[2] False Messiahs have continued from time to time to appear among the Jews. Such was Serenus of Syria (*circa* 720 A.D.). Messianic hopes were active at the time of the fall of the Omayyads, and led to a serious rising under Abu 'Isa of Ispahan, who called himself forerunner of the Messiah. The false Messiah David Alrui (Alroy) appeared among the warlike Jews in Azerbijan in the middle of the 12th century. The Messianic claims of Abraham Abulafia of Saragossa (born 1240) had a cabalistic basis, and the same studies encouraged the wildest hopes at a later time. Thus Abarbanel calculated the coming of the Messiah for 1503 A.D.; the year 1500 was in many places observed as a preparatory season of penance; and throughout the 16th century the Jews were much stirred and more than one false Messiah appeared. For the false Messiah Sabbathai, see vol. xiii. p. 681.

[3] The province occupies the north-east corner of the island, and is 60 miles in length by 30 in breadth. It is chiefly occupied with mountain ranges and valleys; there are few plains. The largest river is the

situated on the Straits of Messina (at this point about 4 miles wide), 8 miles north-west of Reggio and 130 miles east by north of Palermo, in 38° 15′ N. lat., 15° 30′ E. long. The town is built between the sea and a range of sharp and rugged hills, called the Dinnamare, 3707 feet at their highest point. It runs in a semicircle round the harbour, and presents a picturesque appearance from the sea, as the houses rise in tiers upon the slope of a hill, and behind are the wooded mountains.

Messina is the second town of Sicily in importance and in size. Its population was 97,074 in 1850, 111,854 in 1871, and 126,497 in 1881. It is an archiepiscopal see, and has a university, founded by the Jesuits in 1548, with a public library of 56,000 volumes.

The excellence of its harbour makes Messina an important trading town. The harbour is formed by a tongue of low land which runs out from the shore in the form of a sickle, and encloses a round basin, open to the north only, where the entrance channel is about 500 yards wide. This basin is 1¼ miles in circumference, and is of such depth that the largest vessels are able to use it. It is estimated that 1300 steamers, with a total of 1,000,000 tons burthen, and 9000 sailing ships, with a total of 500,000 tons burthen, enter the port yearly. The exports of Messina consist chiefly of oranges, lemons, raisins, wine, oil, liquorice, and hides. There is no prominent manufacture; but silk stuffs are made in considerable quantities. Many of the inhabitants are engaged in fishing, chiefly for tunny. Sword-fish also are captured with the harpoon in the Straits during July and August. Coral fishery is a trade of the people. The hills behind Messina produce a strong dark wine, inferior to that which is made in other parts of the island.

Messina has few buildings of importance or antiquity. The sieges and earthquakes from which the town has suffered destroyed most of its monuments. After the great earthquake in 1783 the city was almost entirely rebuilt. The cathedral, the principal building, is a church of the Norman period. It was begun in 1098 by Count Roger I., and finished by his son Roger II. The church is in the form of a Latin cross, 305 feet long and 145 feet wide in the transepts. The lower half of the façade is encrusted with slabs of red and white marble. It has three Gothic portals, with pointed arches and rich ornamentation, belonging to the period of the Anjou dynasty. The nave contains twenty-six columns of Egyptian granite, said to have been brought from an ancient temple of Poseidon which stood near the Faro. The mosaics of the apses date from the year 1330. In the choir are the sarcophagi of the emperor Conrad IV. (d. 1254), of Alphonso the Generous (d. 1458), and of Antonia, widow of Frederick III. of Aragon. In 1254 the cathedral was seriously damaged by fire; in 1559 the campanile was burned down; in 1783 the earthquake overthrew the campanile and the transept. The building therefore offers a mixture of styles,—first Norman, then Gothic, then Early Renaissance, finally Barocco and Modern Gothic.

The history of Messina begins very early. It is said to have been founded, on the site of a more ancient Sicilian town, by pirates from Cumæ, in 732 B.C. It took its earlier name of Zancle (a sickle) from the shape of its harbour. The number of its inhabitants was increased by an influx of Chalcidians under Cratæmenes; and in 649 B.C. the town was sufficiently prosperous and populous to establish a colony at Himera. The Samians occupied Zancle for a short time after Miletus had been captured by the Persians in 494 B.C. In the following year the city fell into the hands of Anaxilas, tyrant of Rhegium, who introduced a population of Messenians, from Messenia in the Peloponnesus; and they changed the name of the place to Messana, in the Doric pronunciation, to remind them of their fatherland. The sons of Anaxilas were expelled from the government of Messina in 466 B.C., and a republic established; and this government was continued until Messina fell into the hands of the Carthaginians during their wars with Dionysius the elder of Syracuse (396 B.C.). The Carthaginians destroyed the city; but Dionysius recaptured and rebuilt it. During the next fifty years Messina changed masters several times, till Timoleon finally expelled the Carthaginians in 343 B.C. In the wars between Agathocles of Syracuse and Carthage, Messina took the side of the Carthaginians. Agathocles's mercenaries, the Mamertines, treacherously seized the town in 288 B.C. and held it. They came to war with Hiero II. of Syracuse, after Agathocles's death; and Hiero's allies, the Carthaginians, helped him to reduce Messina. The Mamertines appealed for help to Rome, which was granted, and this led to a collision between Rome and Carthage, which ended in the First Punic War. At the close of that war, in 241 B.C., Messina became a possession of the Romans. During the civil wars which followed the death of Julius Cæsar, Messina held with Sextus Pompeius; and in 35 B.C. it was sacked by Octavian's troops. After Octavian's proclamation as emperor he founded a colony here; and Messina continued to flourish as a trading port. In the division of the Roman empire it belonged to the emperors of the East; and in 547 A.D. Belisarius collected his fleet here before crossing into Calabria. The Saracens took the city in 831 A.D.; and in 1061 it was the first permanent conquest made in Sicily by the Normans under Roger d'Hauteville. In 1190 Richard Cœur de Lion with his crusaders passed six months in Messina. He fell out with Tancred, the last of the Hauteville dynasty, and sacked the town. In 1194 the city, with the rest of Sicily, passed to the house of Hohenstaufen under the emperor Henry VI., who died there in 1197. At the time of the Sicilian Vespers (1282), which drove the French out of Sicily, Messina bravely defended itself against Charles of Anjou, and repulsed his attack. Peter I. of Aragon, through his commander Ruggiero di Loria, defeated the French off the Faro; and from 1282 to 1713 Messina remained a possession of the Spanish royal house. In 1571 the fleet fitted out by the Holy League against the Turk assembled at Messina, and in the same year its commander, Don John of Austria, celebrated a triumph in the city for his victory at Lepanto. Don John's statue stands in the Piazza dell' Annuziata. For one hundred years, thanks to the favours and the concessions of Charles V., Messina enjoyed great prosperity. But the internal quarrels between the Merli, or aristocratic faction, and the Malvezzi, or democratic faction, fomented as they were by the Spaniards, helped to ruin the city (1671–78). The Messinians suspected the Spanish court of a desire to destroy the ancient senatorial constitution of the city, and sent to France to ask the aid of Louis XIV. in their resistance. Louis despatched a fleet into Sicilian waters, and the French occupied the city. The Spaniards replied by appealing to Holland, who sent a fleet under Ruyter into the Mediterranean. The French admiral, Duquesne, defeated the combined fleet of Spain and Holland, but, notwithstanding this victory, the French suddenly abandoned Messina in 1678, and the Spanish occupied the town once more. The senate was suppressed, and Messina lost its privileges. This was fatal to the importance of the city, and it never recovered. In 1743 the plague carried off 40,000 inhabitants. The city was partially destroyed by earthquake in 1783. During the revolution of 1848 against the Bourbons of Naples, Messina was bombarded for three consecutive days. In 1854 the deaths from cholera numbered about 15,000. Garibaldi landed in Sicily in 1860, and Messina was the last city in the island taken from the Bourbons and made a part of united Italy under Victor Emmanuel.

Messina was the birthplace of the following celebrated men: Dicæarchus, the historian (*cir.* 322 B.C.); Aristocles, the Peripatetic; Euhemerus, the rationalist (*cir.* 316 B.C.); Stefano Protonotario, Mazzeo di Ricco, and Tommaso di Sasso, poets of the court of Frederick II. (1250 A.D.); and Antonello da Messina, the painter (1447–99), five of whose works are preserved in the university gallery. During the 15th century the grammarian Constantine Lascaris taught in Messina; and Bessarion was for a time archimandrite there.

METALLURGY, a branch of applied science whose object is to describe and scientifically criticize the methods used industrially for the extraction of metals from their ores. Of the large number of metals enumerated in the handbooks of chemistry, the vast majority, of course, lie outside its range; but it is perhaps as well for us to point out that in metallurgic discussions even the term "metallic," as applied to compounds, has a restricted meaning, being exclusive of all the light metals, although one of these, namely aluminium, is being manufactured industrially. The following table enumerates in the order of their importance the metals which our subject at present

Alcantara. The chief towns are Messina, Castroreale, Mistretta, Patti, and Milazzo. The population in 1854 was 380,279, in 1871 420,649, and in 1881 467,233.

is understood to include: the second column in each case gives the chemical characters of the native compounds utilized, italics indicating ores of subordinate importance. The term "oxide" must be understood to include carbonate, hydrate, and occasionally (when marked in the table with *) silicate.

Metal	Character of Ores.
Iron	Oxides, *sulphide.*
Copper	Complex sulphides, also oxides, *metal.*
Silver	Sulphide and reguline metal, *chloride.*
Gold	Reguline metal.
Lead	Sulphide and basic-carbonate, *sulphate*, &c.
Zinc	Sulphide, oxide *
Tin	Oxide.
Mercury	Sulphide, reguline metal.
Antimony	Sulphide.
Bismuth	Reguline metal.
Nickel and cobalt	Arsenides
Platinum and platinum metals	Reguline.
Aluminium	Oxide,* sodio-fluoride.

excess of unburned oxygen; or it is meant to deoxidize ("reduce") the ore, when the draught must be restricted so as to keep the ore constantly wrapped up in combustible flame gases (carbonic oxide, hydrogen, marsh-gas, &c.). The vast majority of the chemical operations of metallurgy fall into this category, and in these processes other metal-reducing agents than those naturally contained in the fire (or wind) are only exceptionally employed.

2. *Amalgamation.*—The ore by itself (if it happens to be a reguline one), or the ore plus certain reagents (if it does not), is worked up with mercury so that the metal is obtained ultimately as an amalgam, which can be separated mechanically from the dross. The purified amalgam is subjected to distillation, when the mercury is recovered as a distillate while the metal remains.

3. *Wet Processes.*—Strictly speaking, certain amalgamation methods fall under this head; but, in its ordinary acceptance, the term refers to processes in which the metal is extracted either from the natural ore, or from the ore as it is after roasting or some other preliminary treatment, by means of an aqueous acid or salt solution, and from this solution precipitated—generally in the reguline form—by some suitable reagent.

Few methods of metal extraction at once yield a pure product. What as a rule is obtained is a more or less impure metal, which requires to be "refined" to become fit for the market. We now pass to the individual consideration of the several steps referred to.

Comminution of Ores.—Assuming the ore to be given in the shape of large lumps, these must first be broken up into small stones (of about the size of those used for macadamizing a road) before they can go to the grinding-mill. This formerly used to be done by handwork; nowadays it is preferably effected by means of an American invention called the stone-breaker (fig. 1). This consists essentially of two substantial vertical iron plates; one is fixed, the other is connected with an excentric worked by an engine so as to alternately dash against and recede from the former. The lumps of ore, in passing through this jaw-like contrivance, are broken up into smaller fragments fit for

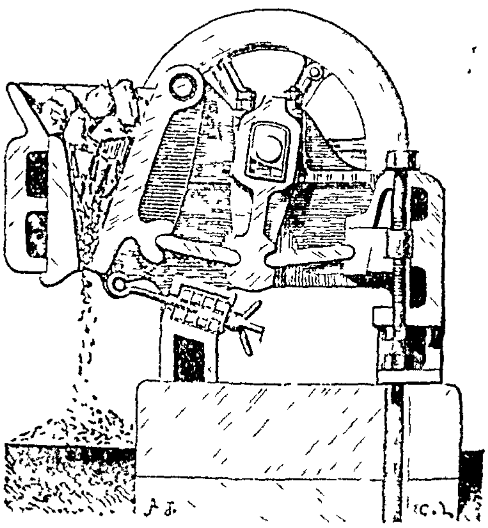


Fig. 1.—American Stone-Breaker.

the mill. For the production of a coarse powder revolving cylinders are often employed. Two cylinders of equal diameter and length, made of iron, steel, or stone, are suspended by parallel axes in close proximity to each other. The width of the slit between them can be made to vary according to the requirements of the case. The cylinders are made to revolve in opposite directions, so that the stones when run into the groove formed by their upper halves are drawn between them and are crushed into bits of a size depending on the least *distance between the two surfaces* Exceptionally hard stones might bring the machine to a standstill or cause breakages; hence only one of the two axes of rotation is absolutely fixed; the cushions of the other are only held in relatively fixed positions, each between a couple of guiding rails, by means of powerful springs at their backs. The springs are made of alternate disks of india-rubber and sheet-iron, and *yield appreciably only* to very strong pressures. When an exceptionally hard stone comes on, they yield

and allow it to pass through uncrushed. Sometimes two sets of cylinders are arranged one above the other, so that the grit from the upper falls into the jaws of the lower set to receive further comminution. The diameter of the cylinders is from a foot to a yard, their length from 9 inches to a yard, the velocity of a point on the periphery a foot to a yard per second. The quantity of ore reduced per hour per horse-power is about 5 cubic feet for quartz or other hard minerals, and about 14 cubic feet for minerals of moderate hardness.

For the production of a relatively fine powder the pounding-mill is frequently used, which, in its action, is analogous to a mortar and pestle. The mortar is a rectangular trough, while the pestle is replaced by a parallel set of heavy metal or metal-shod beams, which (by means of a revolving cylinder with cogs catching projections on the beams) are lifted up in succession and then let fall by their own weight so as to pound up the ore in the trough. The ore is supplied from a prismatic reservoir with a sloping bottom leading into a canal through which the stones slide into the trough. A current of water, which constantly flows into the trough from below, lifts up the finer particles and carries them away over the edge of the trough into a settling tank.

The object pursued in powdering an ore is to prepare it for being purified by washing. But the velocity with which a solid particle falls through water depends on its size as well as on its specific gravity—an increase in either accelerating the fall: hence, where the difference in specific gravity between the things to be separated is small, the washing must be preceded by a separation of the ore-powder into portions of approximately equal fineness. This is often effected by passing the ore through a system of sieves of different width of mesh superposed over one another, the coarser sieve always occupying the higher position. Sometimes the sieves are made to "go dry," sometimes they are aided in their action by a current of water which, more effectually than mere shaking, prevents adherence of dust to coarser parts.

Another contrivance is the "Drum" (fig. 2). A long perforated circular cylinder made of sheet-iron, open at both ends, is suspended, in a sloping position, by a revolving shaft passing through its axis. The size of the perforations is generally made to increase in passing from the upper to the lower belts of the cylinder. While the drum

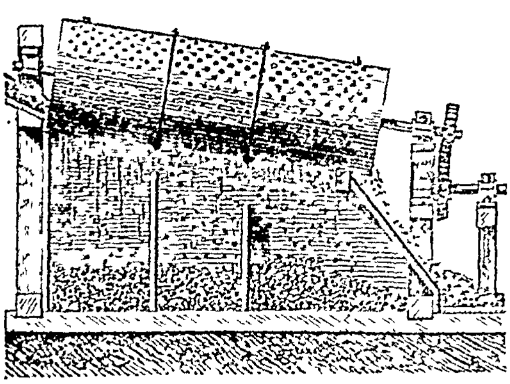


FIG. 2.—Drum.

is revolving, the ore, suspended in water, flows in at the upper end, and in travelling down it casts off first its finest and then its coarser parts, the coarsest only reaching the exit at the lower end. The several grades of powder produced fall each into a separate division of the collecting tank.

The drum, of course, is subject to endless modifications. A very ingenious combination is H. E. Taylor's "Drum Dressing Machine" (fig. 3). It consists of three truncated cone-shaped drums D, fixed co-axially to the same horizontal revolving shaft,

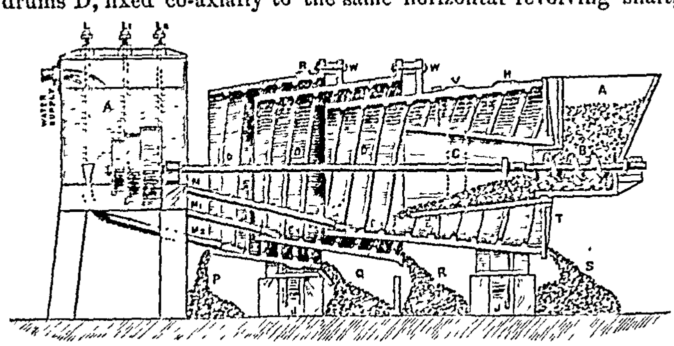


FIG. 3.—Taylor's Drum Dressing Machine.

so that the narrow end of No. 1 projects into the wider end of No. 2, and No. 2 similarly into No. 3. The drums are not perforated, but are armed inside with screw-threads formed of strips of sheet metal fixed edgeways to the drum. The ore grit to be dressed is placed in a hopper A, and from it, by a worm B fixed to the revolving shaft, is being screwed forward into a short fixed truncated cone C projecting into the revolving drum No. 1, into which it flows in a constant current. The rotary motion of the drum tends to convey the ore along the spiral path prescribed by the screw-thread towards the other end, and from it into drum No. 2, and so on. But the ore in each drum meets with a jet of water E impelling it the opposite way, and the effect is that, in each drum, the lighter parts follow the water, and with it run off over the entrance edge to be collected in a special tank, while the coarser parts roll down the spiral path toward the next drum to undergo further parting. The tank or pit for drum 1 receives the finest and lightest parts, that of drum 2 a heavier, that of drum 3 a still heavier portion, while only the very heaviest matter finds its way out of the exit end of No. 3 into a fourth receptacle.

Of the large number of other ore-dressers, only two need be mentioned here.

The "Clausthal Turn-Table" consists of a circular table, the surface of which rises from the periphery towards the centre so as to form a very flat cone of about 170°, which is fixed co-axially to a vertical rotary shaft. At the apex of the table, surrounding the shaft, but independent of its motion, there is a circular trough of sheet zinc, divided into two compartments; one receives a stream of water carrying the ore, the other a supply of pure water. A large annular trough of sheet zinc is placed below the periphery of the table, so as to receive whatever may fall over the edge. It also is divided into compartments, as shall be explained further on. Supposing the table to be at rest, a sector of about 60° of it would be constantly run over by the ore-mud out of the first compartment of the upper trough. This mud current would suffer partial separation into heavier and lighter parts,—rich ore resting in the higher and poorer in the lower latitudes, and a still poorer ore falling over the periphery into the lower trough. The same happens with the moving table; only each sector of such partially analysed ore undergoes further purification by passing through about 90° of water-shower. After passing this, it meets with a perforated fixed water-pipe going up radially to about half the radius of the table. This pipe also carries sweeping brushes, so that the belt of ore from the lower latitudes of the table is swept off into the corresponding section of the receiving trough. What of ore remains on the higher latitudes subsequently meets with a similar arrangement which sweeps it off into its compartment. If the table turns from the left to the right, and we follow the process, beginning at the left edge of the ore-mud compartment, it will be seen that a first sector of the receiving trough gathers the light dross, a succeeding one an intermediate product, a third the most highly purified ore. The "intermediate" is generally run into the ore-mud trough of a second table to be further analysed.

In the "Continuous Wash-Pumps" (Continuirliche Setzpumpe) of the Harz, three funnel-shaped vessels (one of which is shown in fig. 4) are set in a frame beside one another, but at different levels, so that any overflow from No. 1 runs into No. 2 and thence into No. 3. Each funnel communicates below with its own compartment of a common cistern. Into each funnel a riddle with narrow meshes is inserted somewhere near the upper end, while, beside the riddle, there is a pump of short range, which, by means of an excentric, is worked so that the piston alternately goes rapidly down and slowly up. The mode of working is best explained by an example. At Breinigerberg in Rhenish Prussia the apparatus serves to separate a complex ore into the following four parts, which we enumerate in the order of their specific gravities—(1) galena (the heaviest), (2) pyrites, (3) blende, (4) dross. Sieve No. 1 is charged with granules of galena, just large enough not to slip through the meshes, No. 2 similarly with granules of pyrites, No. 3 with those of blende. The crude ore-mud goes into sieve 1; the jerking action of the pump alternately tosses the particles up into the water and allows them to fall; the heaviest naturally come down first, but what is most striking is that nothing will pass through the bed of galena but what is at least as heavy as galena itself. In a similar manner No. 2 and No. 3

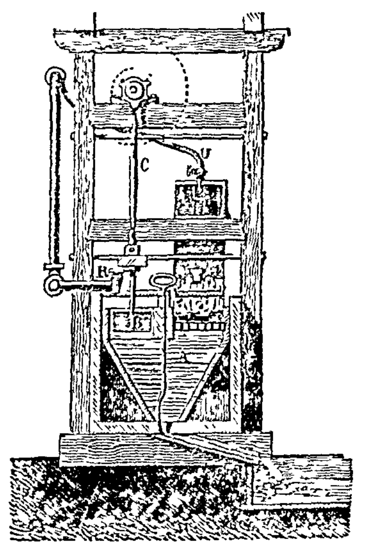


FIG. 4.—Continuous Wash-Pump.

funnels sift out the pyrites and the blende respectively, so that almost nothing but dross runs off ultimately. The apparatus is said to do its work with a wonderful degree of precision, and of course is susceptible of wider application, but it ceases to work when the raw material is a slime so fine that the particles fall too slowly.

Modes of Producing High Temperatures.—Most of what is to be said on this topic has already been anticipated in the articles FUEL, FURNACE, and BELLOWS; but a few notes may be added on specially metallurgic points.

Furnace Materials.—In a metallurgic furnace the working parts at least must be made of special materials capable of withstanding the very high temperatures to which they are exposed and the action of the fluxes which may be used. No practically available material fully meets both requirements, but there is no lack of merely fire-proof substances.

Of native stones, a pure quartzose sandstone, free from marl, may be named as being well adapted for the generality of structures; but such sandstone, or indeed any kind of fire-proof stone, is not always at hand. What is more readily procured, and consequently more widely used, is refractory brick, made from "fire-clay." The characteristic chemical feature of fire-clays is that in them the clay proper (always some kind of hydrated silicate of alumina) is associated with only small proportions of lime, magnesia, ferrous oxide, or other protoxides. If the percentage of these goes beyond certain limits, the bricks, when strongly heated, melt down into a slag. The presence of free silica, on the other hand, adds to their refractoriness. In fact the best fire-bricks in existence are the so-called Dinas bricks, which consist substantially of silica, contaminated only with just enough of bases to cause it to frit together on being baked. Dinas bricks, however, on account of their high price, are reserved for special cases involving exceptionally high temperatures. Amongst ordinary fire-bricks those from Stourbridge enjoy the highest reputation. It follows from what has just been said that, in a metallurgic furnace, lime-mortar cannot be used as a cement, but must be replaced by fire-clay paste.

In the construction of cupels, reverberatory furnaces, &c., only the general groundwork is, as a rule, made of built bricks, and this groundwork is coated over with some kind of special fire-proof and flux-proof material, such as bone-ash, a mixture of baked fire-clay and cokes or graphite, or of quartz and very highly silicated slags, &c. These beddings are put on in a loose powdery form, and then stamped fast. They offer the advantage that, when worn out, they are easily removed and renewed. The powerful draught which a metallurgic fire needs can be produced by a chimney, where the fuel forms a relatively shallow layer spread over a large grating; but, when closely-packed deep masses of fuel or fuel and ore have to be kept ablaze, a blast becomes indispensable.

Chimneys.—The efficiency of a chimney is measured by the velocity V with which the air ascends through it, multiplied by its section; and the former is in roughly approximate accordance with the formula

$$V = k\sqrt{2gh(T - T_0)/T_0},$$

where h stands for the height of the chimney, g for the acceleration of gravity (32·2 feet per second), and T and T_0 for the absolute temperatures (meaning the temperatures counted from −273° C.) of the air within and the air without the chimney respectively, while k is a factor meant to account for the resistances which the air, in its progress through the furnace, &c., has to overcome. In practice T is taken as the mean temperature of the chimney gases, which theoretically is not unobjectionable; but the weakest point in the formula is the smallness and utter inconstancy of the factor k, which, according to Péclet, generally assumes some value of the power $\frac{1}{2}$, $\frac{1}{3}$, &c. Yet the formula is of some use as enabling one to see the way in which V depends on h and $(T - T_0)/T_0$ conjointly,—to see, for instance, how deficient chimney height may be compensated for by an increase of temperature in the chimney gases, and *vice versa*.

Blowing-Machines.—Of the several kinds of blowers described under BELLOWS (*q.v.*), the "fans" are the best means for producing large volumes of wind of relatively small but steady pressure; "bellows" are indicated in the case of work on a relatively small scale requiring moderate wind pressure; while the "cylinder blast" comes in where large masses of high-pressure wind are required. Two highly interesting blowing-machines, however, are omitted in that article, which may be shortly described here.

The "Water Blast" (Wassertrommelgebläse) is interesting historically, having been used metallurgically in Hungary for many centuries. A mass of water, stored up in a reservoir, is made to fall down continuously through a high narrow vertical shaft having air-holes at its upper end. The vertical column of water sucks in air through these holes and carries it down with it into a kind of inverted tub standing in a reservoir kept at a constant level. Air and water there separate, the former flowing away through a pipe into a wind-box, from which it is led to its destination.

The "Cagniardelle" (figs. 5, 6), so called from its inventor Cagniard Latour, also utilizes water to carry air, but in quite another way. By means of a round shaft passing through its axis, a cylindrical drum of sheet-metal is suspended slantingly in a mass of water, so that the lower end is fully immersed, while of the upper end the segment above the upper side of the shaft is uncovered. The space between shaft and drum is converted into a very wide screw-shaped canal by a band of sheet-metal hermetically fixed edgeways to the two. Both the top and the bottom end of the drum are partially closed by flat

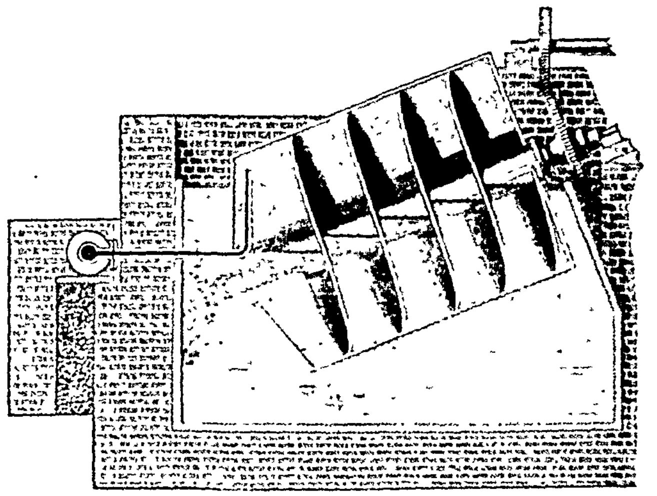


FIG. 5.—Cagniardelle.

bottoms soldered or riveted to the respective edges; the lower one leaves a ring-shaped opening between its edge and the shaft, which serves for the introduction of a fixed air-pipe bent so as to reach up to near the top of the drum's air-space; in the upper bottom three quadrants are closed, *the fourth is open*. Supposing the screw-canal, traced from below, to go from the left to the right, the drum is made to revolve in the same sense, and the effect is that, in each revolution, the screw-canal at its top end swallows a certain volume of air which, by the succeeding entrance of the water—which, of course, moves relatively to the screw—is pushed towards and ultimately into the air-space at the bottom end. The Cagniardelle yields a perfectly continuous blast, and, as it is not encumbered with any dead resistances except the friction of the shaft against its bearings (which can be reduced to very little) and the very slight friction of the water against the screw-canal, it utilizes a very large percentage of the energy spent on it. This percentage, according to experiments by Schwamkrug, amounts to from 75 to 84·5; in the case of the cylinder-blast it is 60 to 65 per cent.; with bellows, about 40 per cent.; with the "Wassertrommelgebläse" 10 to 15 per cent. Hence the "Wassertrommelgebläse" stands last in relative efficiency; but we must not forget that it alone directly utilizes native energy, while, in the cylinder blast, for example, 100 units of work done by the steam-engine involve a vastly greater energy spent on the engine as heat.

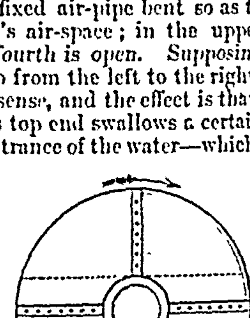


Fig. 6.

To maintain a desired temperature in a given furnace charged in a certain manner, the introduction of a certain volume of air per unit of time is necessary. But this quantity, in a given blowing-machine, is determined by the over-pressure of the wind, as measured by a manometer, the velocity of the wind being approximately proportional to $\sqrt{M/(B+M)}$, where M stands for the height of the mercury-manometer, and B for that of the barometer. Hence the practical metallurgist, in adjusting his blast, has nothing to do but to see that the manometer shows the reading which, by previous trials, has been proved to yield an adequate supply of wind.

Fuel.—In some isolated cases the ore itself, by its combustion, supplies the necessary heat for the operation to be performed upon it. Thus, for instance, the roasting of blackband iron-stone is effected by simply piling up the ore and setting fire to it, so that the ore is at the same time its own furnace and fuel; in the Bessemer process of steel-making, the burning carbon of the pig-iron supplies the heat necessary for its own combustion; and a similar process has been tried experimentally, and not without success, for the working up of certain kinds of pyrites. But, as a rule, the high temperatures required for the working of ores are produced by the combustion of extraneous fuel, such as wood, wood-charcoal, coal, coke. Of these four, wood-charcoal is of the widest applicability, but not much used in Britain on account of its high price. High-class coke or pure anthracite, volume for volume,

gives the highest temperature. Wood or coal is indicated when a voluminous flame is one of the requisites. Obviously fuel of the same kind and quality gives a higher calorific intensity when, before use, it is deprived by drying of its moisture, or when it is used in conjunction with a hot instead of a cold blast. This latter principle, as every one knows, is largely discounted in the manufacture of pig-iron, where nowadays coal, with the help of the hot blast, is made to do what formerly could only be effected with charcoal or coke. For further information see FUEL and IRON.

Chemical Operations.—In regard to processes of amalgamation and to wet-way processes, we have nothing to add to what was given in a previous paragraph;[1] we therefore here confine ourselves, in the main, to pyro-chemical operations.

The method to be adapted for the extraction of a metal from its ore is determined chiefly, though not entirely, by the nature of the non-metallic component with which the metal is combined. The simplest case is that of the reguline ores where there is no non-metallic element. The important cases are those of GOLD, BISMUTH, and MERCURY (*q.v.*).

Oxides, Hydrates, Carbonates, and Silicates.—All iron and tin ores proper fall under this heading, which, besides, comprises certain ores of copper, of lead, and of zinc. In any case the first step consists in subjecting the crude ore to a roasting process, the object of which is to remove the water and carbonic acid, and burn away, to some extent at least, what there may be of sulphur, arsenic, or organic matter. The residue consists of an impure (perhaps a very impure) oxide of the respective metal, which in all cases is reduced by treatment with fuel at a high temperature. Should the metal be present in the silicate form, lime must be added in the smelting to remove the silica and liberate the oxide.

In the case of zinc the temperature required for the reduction lies above the boiling point of the metal; hence the mixture of ore and reducing agent (charcoal is generally used) must be heated in a retort combined with the necessary condensing apparatus. In all the other cases the reduction is effected in the fire itself, a tower-shaped blast furnace being preferably used. The furnace is charged with alternate layers of fuel and ore (or rather ore and flux, see below), and the whole kindled from below. The metallic oxide, partly by the direct action of the carbon with which it is in contact, but principally by that of the carbonic oxide produced in the lower strata from the oxygen of the blast and the hot carbon there, is reduced to the metallic state; the metal fuses and runs down, with the slag, to the bottom of the furnace, whence both are withdrawn by the periodic opening of plug-holes provided for the purpose.

Sulphides.—Iron, copper, lead, zinc, mercury, silver, and antimony very frequently present themselves in this state of combination, as components of a very numerous family of ores which may be divided into two sections: (1) such as substantially consist of simple sulphides, as iron pyrites (FeS_2), galena (PbS), zinc blende (ZnS), cinnabar (HgS); and (2) complex sulphides, such as the various kinds of sulphureous copper ores (all substantially compounds or mixtures of sulphides of copper and iron); bournonite, a complex sulphide of lead, antimony, and copper; rothgiltigerz, sulphide of silver, antimony, and arsenic; fahlerz, sulphides of arsenic and antimony, combined with sulphides of copper, silver, iron, zinc, mercury, silver; and mixtures of these and other sulphides with one another.

In the treatment of a sulphureous ore, the first step as a rule is to subject it to oxidation by roasting it in a reverberatory or other furnace, which, in the first instance, leads to the burning away of at least part of the arsenic and part of the sulphur. The effect on the several individual metallic sulphides (supposing only one of these to be present) is as follows:—

1. Those of silver (Ag_2S) and mercury (HgS) yield sulphurous acid gas and metal; in the case of silver, sulphate is formed as an intermediate product, at low temperatures. Metallic mercury, in the circumstances, goes off as a vapour, which is collected and condensed; silver remains as a regulus, but pure sulphide of silver is hardly ever worked.

2. Sulphides of iron and zinc yield the oxides Fe_2O_3 and ZnO as final products, some basic sulphate being formed at the earlier stages, more especially in the case of zinc. The oxides can be reduced by carbon.

3. The sulphides of lead and copper yield, the former a mixture of oxide and normal sulphate, the latter one of oxide and basic sulphate. Sulphate of lead is stable at a red heat; sulphate of copper breaks up into oxide, sulphurous acid, and oxygen. In practice, neither oxidation process is ever pushed to the end; it is stopped as soon as the mixture of roasting-product and unchanged sulphide contains oxygen and sulphur in the ratio of $O_2:S$. The access of air is then stopped and the whole heated to a higher temperature, when the potential SO_2 actually goes off as sulphurous-acid gas and the whole of the metal is eliminated as such. This method is largely utilized in the smelting of lead (from galena) and of copper from copper pyrites. In the latter case, however, the sulphide Cu_2S has first to be produced from the ore, which is done substantially as follows. The ore is roasted with silica until a certain proportion of the sulphur is burned away as SO_2, while a corresponding proportion of oxygen has gone to the metal part of the ore. Now it so happens that copper has a far greater affinity for sulphur than iron has; hence any locally produced oxide of copper, as long as sufficient sulphide of iron is left, is sure to be reconverted into sulphide, and the final result is that, while a large quantity of oxidized iron passes into the slag, all the copper and part of the iron separate out as a mixed regulus of Cu_2S and FeS ("mat"). This regulus, by being fused up repeatedly with oxidized copper ores or rich copper slags (virtually with CuO and silica), gradually yields up the whole of its iron, so that ultimately a regulus of pure subsulphide of copper, Cu_2S ("fine mat"), is obtained, which is worked up for metal as above explained.

4. Sulphide of antimony, when roasted in air, is converted into a kind of alloy of sulphide and oxide; the same holds for iron, only its oxysulphide is quite readily converted into the pure oxide Fe_2O_3 by further roasting. Oxysulphide of antimony, by suitable processes, can be reduced to metal, but these processes are rarely used, because the same end is far more easily obtained by "precipitation," *i.e.*, withdrawing the sulphur by fusion with metallic iron, forming metallic antimony and sulphide of iron. Both products fuse, but readily part, because fused antimony is far heavier than fused sulphide of iron is. A precisely similar method is used occasionally for the reduction of lead from galena. Sulphide of lead when fused together with metallic iron in the proportion of 2Fe : 1PbS yields a regulus (=1Pb) and a "mat" Fe_2S, which, however, on cooling, decomposes into FeS parts of ordinary sulphide and Fe parts of finely divided iron. What we have just been explaining are only two special cases of a more general metallurgic proposition. According to Fournet, any one of the metals copper, iron, tin, zinc, lead, silver, antimony, arsenic, in general, is capable of desulphurizing or precipitating (at least partially) any of the others that follows it in the series just given, and it does so the more readily and completely the greater the number of intervening terms. Hence, supposing a complete mixture of these metals to be melted down under circumstances admitting of only a partial sulphuration of the whole, the copper has the best chance of passing into the "mat," while the arsenic is the first to be eliminated as such, or, in the presence of oxidants, as oxide.

Arsenides.—Although arsenides are amongst the commonest impurities of ores generally, ores consisting essentially of arsenides are comparatively rare. The most important of them are certain double arsenides of cobalt and nickel, which in practice, however, are always contaminated with the arsenides or other compounds of foreign metals, such as iron, manganese, &c. The general mode of working these ores is as follows. The ore is first roasted by itself, when a part of the arsenic goes off as such and as oxide (both volatile), while a complex of lower arsenides remains. This residue is now subjected to careful oxidizing fusion in the presence of glass or some other fusible solvent for metallic bases. The effect is that the several metals are oxidized away and pass into the slag (as silicates) in the following order,—first the manganese, secondly the iron, thirdly the cobalt, lastly (and very slowly) the nickel; and at any stage the as yet unoxidized residue of arsenide assumes the form of a fused regulus, which sinks down through the slag as a "speis." (This term, as will readily be understood, has the same meaning in reference to arsenides as "mat" has in regard to sulphides.) By stopping the process at the right moment, we can produce a speis which contains only cobalt and nickel, and if at this stage also the flux is renewed we can further produce a speis which contains only nickel and a slag which substantially is one of cobalt only. The composition of the speises generally varies from $AsMe_{3\cdot2}$ to $AsMe_2$, where "Me" means one atomic weight of metal in toto, so that in general $1Me = xFe + yCo + zNi$, where $x+y+z=1$. The siliceous cobalt is utilized as a blue pigment called "smalte"; the nickel-speis is worked up for metal, preferably by wet processes.

Minor Reagents.—Besides the oxidizing and reducing agents naturally present in the fire, and the "fluxes" added for the production of slags, there are various minor reagents; of which the more important may be noticed here. One—namely, metallic iron as a desulphurizer—has already been referred to.

Oxide of lead, PbO (litharge), is largely used as an oxidizing agent. At a red heat, when it melts, it readily attacks all metals, except silver and gold, the general result being the formation of a mixed oxide and of a mixed regulus, a distribution, in other words, of both the lead and the metal acted on between slag and regulus. More important and more largely utilized is its action on metallic sulphides, which, in general, results in the formation of three things besides sulphurous acid gas, viz., a mixed oxide slag including the excess of litharge, a regulus of lead (which may include bismuth and other more readily reducible metals), and, if the litharge is not sufficient for a complete oxidation, a "mat" comprising the more readily sulphurizable metals. Oxide of lead, being a most powerful solvent for metallic oxides generally, is also

[1] Examples are given in GOLD and COPPER. See also SILVER.

largely used for the separation of silver or gold from base metallic oxides.

Metallic lead is to metals generally what oxide of lead is to metallic oxides. It accordingly is available as a solvent for so to say licking up small particles of metal diffused throughout a mass of slag or other dross, and uniting them into one regulus. This naturally leads us to consider the process of "cupellation," which discounts the solvent powers of both metallic lead and its oxide. This process serves for the extraction of gold and silver from their alloys with base metals such as copper, antimony, &c. The first step is to fuse up the alloy with a certain proportion of lead, which is determined by the weight of base metal to be eliminated, and is always sufficient to produce a lead-alloy of low fusing point. This alloy is heated on a shallow dish-shaped bed of bone earth to redness, and at this temperature subjected to the action of air. The base metals (copper, &c.) are oxidized away, the first portions as an infusible scum containing little oxide of lead, the latter in the form of a solution in molten litharge. Lead is, in general, less oxidizable than the other base metals; hence the last instalment of liquid litharge which runs off is pure, and the ultimately remaining regulus consists of silver and gold only. These latter may be separated by nitric acid or boiling oil of vitriol, which converts the silver into soluble salts and leaves the gold.

Oxide of iron, and also binoxide of manganese, are used for the decarburation of pig-iron. The oxygen of the reagent burns the carbon of the pig into carbonic acid, while the metal of the reagent becomes iron and FeO or MnO respectively, the oxides uniting with the silica added as such, or formed by the oxidation of the silicon of the pig, into a fusible slag.

Iron pyrites, FeS_2, is employed for the preliminary concentration of traces of gold diffused throughout slags or base ores. The reagent, through the action of the heat, gives up one-half of its sulphur, which reduces part of the metallic oxides present. The gold and silver unite with what is left of protosulphide of iron (FeS) into a mat, which is then worked up for the noble metals.

Fluxes.—Practically speaking, all ores are contaminated with more or less of gangue, which in general consists of infusible matter, and consequently, if left unheeded in the reduction of the metallic part of the ore, would retain more or less of the metal disseminated through it, or at best foul the furnace. To avoid this, the ore as it goes into the furnace is mixed with "fluxes" so selected as to convert the gangue into a fusible "slag," which readily runs down through the fuel with the regulus and separates from the latter. The quality and proportion of flux should, if possible, be so chosen that the formation of the slag sets in only after the metal has been reduced and molten; or else part of the basic oxide of the metal to be extracted may be dissolved by the slag and its reduction thus be prevented or retarded. Slags are not, as one might be inclined to think, a necessary evil; if an ore were free from gangue we should add gangue and flux from without to produce a slag, because one of its functions is to form a layer on the regulus which protects it against the further action of the blast or furnace gases. Fluxes may be arranged under the three heads of (1) fluor-spar (which is *sui generis*), (2) basic fluxes, and (3) acid fluxes.

Fluor-spar owes its name to the facility with which it fuses up at a red heat with silica, sulphates of lime and barium, and a few other infusible substances into homogeneous masses. It shows little tendency to dissolve basic oxides, such as lime, &c. One part of fluor-spar liquefies about half a part of silica, four parts of sulphate of lime, and one and a half parts of sulphate of baryta. Upon these facts its wide application in metallurgy is founded.

Carbonate of soda (or potash) may be said to be the most powerful of basic fluxes. It dissolves silica and all silicates into fusible glasses. On the other hand, borax may be taken as a type for the acid fluxes. At a red heat, when it forms a viscid fluid, it readily dissolves up all basic oxides into fusible complex borates. Now the gangue of an ore in general consists either of some basic material such as carbonate of lime (or magnesia), ferric oxide, alumina, &c., or of silica (quartz) or some more or less acid silicate, or else of a mixture of the two classes of bodies. So any kind of gangue might be liquefied by means of borax or by means of alkaline carbonate; but neither of the two is used otherwise than for assaying; what the practical metal-smelter does is to add to a basic gangue the proportion of silica, and to an acid ore the proportion of lime, or, indirectly, of ferrous or perhaps manganous oxide, which it may need for the formation of a slag of the proper qualities. The slag must possess the proper degree of saturation. In other words, taking $SiO_2 + nMeO$ (where MeO means an equivalent of base) as a formula for the potential slag, n must have the proper value. If n is too small, *i.e.*, if the slag is too acid, it may dissolve up part of the metal to be brought out as a silicate; if n is too great, *i.e.*, the slag too basic, it may refuse to dissolve, for instance, the ferrous oxide which is meant to go into it, and this oxide will then be reduced, and its metal (iron in our example) contaminate the regulus. In reference to the problem under discussion, it is worth noting that oxides of lead and copper are more readily reduced to metals than oxide of iron Fe_2O_3 is to FeO, the latter more readily to FeO than FeO itself to metal, and FeO more readily to metal than manganous oxide is. Oxide of calcium (lime) is not reducible at all. The order of basicity in the oxides (their readiness to go into the slag) is precisely the reverse.

Most slags being, as we have seen, complex silicates, it is a most important problem of scientific metallurgy to determine the relations in this class of bodies between chemical composition on the one hand and fusibility and solvent power for certain oxides (CaO, FeO, SiO, &c.) on the other. Now the composition of a silicate can be stated in an infinite number of ways; but there must be one mode of formulation which reduces the law to its simplest terms. The mode adapted by metallurgists is something like the following. If we start with the quantity H_2Cl_2 of muriatic acid or the quantity H_2SO_4 of sulphuric acid, it is clear that to convert either into a normal salt we require such a quantity of base as will convert the H_2 of the acid completely into water; but the quantity of base that does so is that containing one atomic weight of oxygen. Hence it is reasonable to define the quantities K_2O of potash,[1] Na_2O of soda,[1] CaO of lime, MgO of magnesia, FeO of ferrous oxide, $\frac{1}{3}Al_2O_3(=alO)$ of alumina, $\frac{1}{3}Fe_2O_3(=feO)$ of ferric oxide, as representing each "one equivalent" of base also in reference to silica, although silica has a characteristically indefinite basicity. Most slags are alloys or compounds of silicates of Al_2O_3 or Fe_2O_3, and of silicates of protoxides (CaO, &c.), hence their general composition is

$$n(RO + xSiO_2) + m[(fe \text{ or } al)O + xSiO_2].$$

This introduction will enable the reader to understand the following mode of classifying and naming composition in silicates.

Name.	Formula.	Oxygen Ratio. Base. : Acid.	x
I. Singulo-silicates	$\frac{1}{2}SiO_2 + 1MO$	1 : 1	$\frac{1}{2}$
II. Bi-silicates	$1SiO_2 + 1MO$	1 : 2	1
III. Tri-silicates	$\frac{3}{2}SiO_2 + 1MO$	1 : 3	$\frac{3}{2}$

The names are the metallurgic ones; scientific chemists designate Class I. as orthosilicates, Class II. as metasilicates, Class III. as sesquisilicates. In the formulæ M stands for K_2, Ca, Fe, &c., or for al$=\frac{2}{3}$Al, fe$=\frac{2}{3}$Fe, &c.; or, shortly, MO for one equivalent of base as above defined. It should be possible to represent each quality of a silicate as a function of x, $\frac{n}{m}$, and of the nature of the individual bases that make up the RO and (fe or al) O respectively. Our actual knowledge falls far short of this possibility. The problem, in fact, is a very tough one, the more so as it is complicated by the existence of aluminates, compounds such as $Al_2O_3.3CaO$, in which the alumina plays the part of acid, and the occasional existence of compounds of fluorides and silicates in certain slags. The following notes on the fusibility of simple silicates are taken from Plattner's researches.

Of the lime silicates, the tri-silicate melts at 2100° C., the bi-silicate at 2150°.

Magnesia silicates are most refractory. The bi-silicate and tri-silicate melt in the oxyhydrogen flame at 2250°.

Of manganous silicates, the easily fusible bi-silicate is yellow or red; the tri-silicate is more refractory.

Of cuprous (Cu_2O) silicates, the bi-silicate is violet, and melts pretty easily; the singulo-silicate is red, dense, and rather refractory.

Cupric silicates, as slags, hardly exist,—the CuO being always reduced to at least Cu_2O.

Lead silicates all melt readily into yellowish transparent glasses. But they have no standing as slags.

As regards the ferrous silicates, the singulo-silicate (orthosilicate) fuses at 1790° (this is about the composition of iron-puddling slag); the bi-silicate is less readily fusible.

Ferric silicates (unmixed) do not exist as slags,—the Fe_2O_3 being reduced in the fire to 1FeO, although Fe_2O_3 occasionally replaces part of the Al_2O_3 in complex silicates.

Alumina silicates are all infusible in even the hottest furnace fires. They begin to soften in the oxyhydrogen flame at about 2400°. But certain aluminates, for instance the salt $3\,CaO.1Al_2O_3$ according to Sefström, melt at furnace heats.

The fusing points of mixtures of two simple silicates cannot be calculated from those of the components. In many cases it is lower than either of the latter two. Thus for instance most magnesia-lime silicates fuse,—the bi-silicate combination (Mg, Ca)$OSiO_2$ most readily.

Alumina silicates become fusible by addition of a sufficient proportion of silicate of lime at about 1918°. The singulo-silicate and bi-silicate combinations melt into grey glasses. Magnesia acts like lime, and so, in a more limited sense, do ferrous and manganous oxides; but their double compounds with Al_2O_3 and silica are more viscid when fused.

Plattner's work is a bold attempt to deal synthetically with the problem here presented, but it does not go the length of even an approximate solution. No one seems to have done much to continue it; hence in the meantime the metallurgist has, for his

[1] Few slags contain more than traces of alkalies.

guidance, to rely on the very numerous analyses which have been made of slags actually produced (by the rule of thumb) in successful metallurgical operations. For some of such slags also Plattner has determined the fusing points. He found for (1) Freiberg lead slag, 9RO, 3alO, $8SiO_2$; oxygen-ratio, 3 : 4; melting-point at 1317° C.; (2) Freiberg crude slag, 15RO, 3alO, $18SiO_2$; oxygen-ratio, 1 : 1; melting-point at 1331° C.; (3) Freiberg black-copper slag, 24FeO, Al_2O_3, $15SiO_2$; oxygen-ratio, 9 : 10; melting-point at 1338° C.; (4) High-furnace slag, 6CaO, 3alO, $9SiO_2$; oxygen-ratio, 1 : 1; melting-point at 1431° C.[1]

Metallurgic Assaying.—To assay an ore originally meant to execute a set of tentative experiments on a small scale in order to find out the proper mode of working it practically. But nowadays the term is always used in the sense of an analysis carried out to determine the money-value of an ore. For this purpose, in many cases it is sufficient to determine the percentages of the metals for which the ore is meant to be worked. But sometimes nothing short of a complete analysis will do. This holds more especially of ores of iron. As this metal is cheap, the value of an ore containing it depends as much on the nature and relative quantities of the impurities as on the percentage of metal. The proved absence of sulphur and phosphorus may be worth more than an additional 5 per cent. of iron, which latter again would perhaps not compensate for the proved presence of a large percentage of uncombined silica.

An assay to be of any value must start with a fair sample of the object of sale. The fulfilment of this condition in all cases is difficult. The general method is, from say a given ship load of ore, to take out (say) half a ton of ore from a large number of different places and to crush this large sample into small fragments of uniform size, which are well shovelled up together. From different parts of this ore-heap a sample of the second order—amounting to, say, 20 ℔—is then drawn, and rendered more homogeneous by finer powdering and mixing. From this sample of the second (or perhaps from one of the third) order quantities of 1 or 2 ℔ are bottled up for assaying. At the same time the moisture of the ore is determined, on a large scale, by some conventional method, such as the drying of 1 or 2 ℔ in an open basin at 100° C., and weighing of the residue as dry ore. This is done at the sampling place by the firms concerned. The assayer further pounds up and mixes his sample, and then proceeds to determine the percentages of moisture and metal in his own way. He has always the choice between two methods, the dry and the wet. For the majority of gold or silver ores, and for cobalt and nickel ores almost as a rule, certain dry-process tests are preferred as the most exact analytically. In almost all other cases it may be said that the wet method is susceptible of the higher degree of precision, yet even in some of these cases the old dry-process tests are preferred to the present day. For instance, all copper ores in the British Isles are sold by the result of the Swansea assay, a kind of imitation of the process of sulphureous copper-ore smelting; and this, singularly, is adhered to even in the case of such cupriferous materials as are worked by the wet way, although the Swansea assay is well known to lose about 1 per cent. of the copper present. A copper-smelter therefore had better buy 5 per cent. than 10 per cent. copper-pyrites cinders, because in the first case he pays only for four-fifths, while in the latter he must pay for nine-tenths of the copper present. To compensate for this anomaly, empirical methods have been contrived for calculating prices. (W. D.)

METALS. The earliest evidence of a knowledge and use of metals is found in the prehistoric implements of the so-called Bronze and Iron ages. In the earliest periods of written history, however, we meet with a number of metals in addition to these two. The Old Testament mentions six metals—gold, silver, copper, iron, tin, and lead. The Greeks, in addition to these and to bronze, came also to know mercury; and the same set of metals, without additions, forms the list of the Arabian chemists of the 8th and of the Western chemists of the 13th century. During the 15th century Basilius Valentinus discovered antimony; he also speaks of zinc and bismuth, but their individuality was established only at a later period. About 1730–40 the Swede Brand discovered arsenic and cobalt (the former is not reckoned a metal by modern chemists), while the Englishman Ward recognized the individuality of platinum. Nickel was discovered in 1774 by Cronstedt, manganese in 1774 by Scheele. The brothers D'Elhujart, in 1783, prepared tungsten; Hjelm, in 1782, isolated molybdenum from molybdic oxide, where its existence had been conjecturally asserted by Bergmann in 1781. Uranium, as a new element, was discovered by Klaproth in 1789; but his metallic "uranium," after having been accepted as a metal by all chemists until 1841, was then recognized as an oxide by Péligot, who subsequently isolated the true metal. Tellurium was discovered by Müller von Reichenbach in 1782 (again by Klaproth in 1798); titanium, by Klaproth in 1795; chromium, by Vauquelin in 1797; tantalum, by Hatchett in 1801, and by Ekeberg in 1802. Palladium, rhodium, iridium, and osmium (which four metals always accompany platinum in its ores) were discovered, the first two by Wollaston in 1803, the other two by a number of chemists; but their peculiarity was established chiefly by Smithson Tennant.

After Davy, in 1807 and 1808, had recognized the alkalies and alkaline earths as metallic oxides, the existence of metals in all basic earths became a foregone conclusion, which was verified sooner or later in all cases. But the discovery of aluminium by Wöhler in 1828, and that of magnesium by Bussy in 1829, claim special mention. Cadmium, a by no means rare heavy metal, was discovered only in 1818, by Stromeyer.

Of the large number of discoveries of rare metals which have been made in more recent times only a few can be mentioned, as marking new departures in research or offering other special points of interest. In 1861 Bunsen and Kirchhoff, by means of the method of spectrum analysis, which they had worked out shortly before, discovered two new alkali-metals which they called cæsium and rubidium. By means of the same method Crookes, in 1861, discovered thallium; Reich and Richter, in 1863, indium; and Lecoq de Boisbaudran, in 1875, gallium. The existence of the last-named metal had been maintained, theoretically, by Mendelejeff, as early as 1871. The existence of vanadium was proved in 1830 by Sefström; but what he, and subsequently Berzelius, looked upon as the element was, in 1867, proved to be really an oxide by Roscoe, who also succeeded in isolating the true metal.

The development of earlier notions on the constitution of metals and their genetic relation to one another forms the most interesting chapter in the history of chemistry (see ALCHEMY). What modern science has to say on the matter is easily stated: all metals properly so called (*i.e.*, all metals not alloys) are elementary substances; hence, chemically speaking, they are not "constituted" at all, and no two can be related to each other genetically in any way whatever. Our scientific instinct shrinks from embracing this proposition as final; but in the meantime it must be accepted as correctly formulating our ignorance on the subject. All metallic elements agree in this that they form each at least one basic oxide, or, what comes to the same thing, one chloride, stable in opposition to liquid water. This at once suggests an obvious definition of metals as a class of substances, but the definition would be highly artificial and objectionable on principle, because when we speak of metals we think, not of their accidental chemical relations, but of a certain sum of mechanical and physical properties which unites them all into one natural family. What these properties are we shall now endeavour to explain.

All metals, when exposed in an inert atmosphere to a sufficient temperature, assume the form of liquids, which all present the following characteristic properties. They are (at least practically) non-transparent; they reflect light in a peculiar manner, producing what is called "metallic lustre." When kept in non-metallic vessels they take the shape of a convex meniscus. These liquids, when exposed to higher temperatures, some sooner others later, pass into vapours. What these vapours are like is not known in many cases, since, as a rule, they can be produced only at

[1] For further information on slags, see Berthier, *Traité des essais par la voie sèche*; Winkler, *Erfahrungssätze über die Bildung der Schlacken*, Freiberg, 1827; Plattner, *Vorlesungen über allgemeine Hüttenkunde*, i. 28 *sq.*; Percy, *Metallurgy*.

very high temperatures, precluding the use of transparent vessels. Silver vapour is blue, potassium vapour is green, many others (mercury vapour, for instance) are colourless. The liquid metals, when cooled down sufficiently, some at lower others at higher temperatures, freeze into compact solids, endowed with the (relative) non-transparency and the lustre of their liquids. These frozen metals in general form compact masses consisting of aggregates of crystals belonging to the regular or rhombic or (more rarely) the quadratic system. But in many cases the crystals are so closely packed as to produce an apparent absence of all structure. Compared with non-metallic solids, they in general are good conductors of heat and of electricity. But their most characteristic, though not perhaps their most general, property is that they combine in themselves the apparently incompatible properties of elasticity and rigidity on the one hand and plasticity on the other. To this remarkable combination of properties more than to anything else the ordinary metals owe their wide application in the mechanical arts. In former times a high specific gravity used to be quoted as one of the characters of the genus; but this no longer holds, since we have come to know of a whole series of metals which float on water. Let us now proceed to see to what degree the mechanical and physical properties of the genus are developed in the several individual metals.

Non-Transparency.—This, in the case of even the solid metals, is perhaps only a very low degree of transparency. In regard to gold this has been proved to be so; gold leaf, or thin films of gold produced chemically on glass plates, transmit light with a green colour. On the other hand, those infinitely thin films of silver which can be produced chemically on glass surfaces are absolutely opaque. Very thin films of liquid mercury, according to Melsens, transmit light with a violet-blue colour; also thin films of copper are said to be translucent. Other metals, so far as we know, have not been more exactly investigated in this direction.

Colour.—Gold is yellow; copper is red; silver, tin, and some others are pure white; the majority exhibit some modification or other of grey.

Reflexion of Light.—Polished metallic surfaces, like those of other solids, divide any incident ray into two parts, of which one is refracted while the other is reflected,—with this difference, however, that the former is completely absorbed, and that the latter, in regard to polarization, is quite differently affected.[1] The degree of absorption is different for different metals. According to Jamin, the remaining intensity, after one and ten successive perpendicular reflexions respectively from the metal-mirrors named, is as follows (original intensity = 1):—

	Silver.		Speculum Metal.		Steel.	
	1 R.	10 R.	1 R.	10 R.	1 R.	10 R.
Red	·929	·478	·692	·035	·609	·007
Yellow	·905	·339	·632	·010	·599	·006
Violet	·867	·242	·599	·006	·599	·006

This shows the great superiority of silver as a reflecting medium, especially in the case of repeated reflexion.

Crystalline Form.—Most (perhaps all) metals are capable of crystallization, and in most cases isolated crystals can be produced by judiciously managed partial freezing. The crystals belong to the following systems:—*regular system*—silver, gold, palladium, mercury, copper, iron, lead; *quadratic system*—tin, potassium; *rhombic system*—antimony, bismuth, tellurium, zinc, magnesium.

Structure.—Perhaps all metals, in the shape which they assume in freezing, are crystalline, only the degree of visibility of the crystalline arrangement is very different in different metals, and even in the same metal varies according to the slowness of solidification and other circumstances.

Of the ordinary metals, antimony, bismuth, and zinc may be mentioned as exhibiting a very distinct crystalline structure: a bar-shaped ingot readily breaks, and the crystal faces are distinctly visible on the fracture. Tin also is crystalline: a thin bar, when bent, "creaks" audibly from the sliding of the crystal faces over one another; but the bar is not easily broken, and exhibits an apparently non-crystalline fracture.—Class I.

Gold, silver, copper, lead, aluminium, cadmium, iron (pure), nickel, and cobalt are practically amorphous, the crystals (where they exist) being so closely packed as to produce a virtually homogeneous mass.—Class II.

The great contrast in apparent structure between cooled ingots of Class I. and of Class II. appears, however, to be owing chiefly to the fact that, while the latter crystallize in the regular system, metals of Class I. form rhombic or quadratic crystals. Regular crystals expand equally in all directions; rhombic and quadratic ones expand differently in different directions. Hence, supposing the crystals immediately after their formation to be in absolute contact with one another all round, then, in the case of Class II., such contact will be maintained on cooling, while in the case of Class I. the contraction along a given straight line will in general have different values in any two neighbouring crystals, and the crystals consequently become, however slightly, detached from one another. The crystalline structure which exists on both sides becomes visible only in the metals of the first class, and only there manifests itself as brittleness.

Closely related to the structure of metals is their degree of "plasticity" (susceptibility of being constrained into new forms without breach of continuity). This term of course includes as special cases the qualities of "malleability" (capability of being flattened out under the hammer) and "ductility" (capability of being drawn into wire); but it is well at once to point out that these two special qualities do not always go parallel to each other, for this reason amongst others that ductility in a higher degree than malleability is determined by the tenacity of a metal. Hence tin and lead, though very malleable, are little ductile. The quality of plasticity is developed to very different degrees in different metals, and even in the same species it depends on temperature, and may be modified by mechanical or physical operations. A bar of zinc, for instance, as obtained by casting, is very brittle; but when heated to 100° or 150° C. it becomes sufficiently plastic to be rolled into the thinnest sheet or to be drawn into wire. Such sheet or wire then remains flexible after cooling, the originally only loosely cohering crystals having got intertwisted and forced into absolute contact with one another,—an explanation supported by the fact that rolled zinc has a somewhat higher specific gravity (7·2) than the original ingot (6·9). The same metal, when heated to 205° C., becomes so brittle that it can be powdered in a mortar. Pure iron, copper, silver, and other metals are easily drawn into wire, or rolled into sheet, or flattened under the hammer. But all these operations render the metals harder, and detract from their plasticity. Their original softness can be restored to them by "annealing," *i.e.*, by heating them to redness and then quenching them in cold water. In the case of iron, however, this applies only if the metal is perfectly pure. If it contains a few parts of carbon per thousand, the annealing process, instead of softening the metal, gives it a "temper," meaning a higher degree of hardness and elasticity (see below).

What we have called plasticity must not be mixed up

[1] This may be the cause of the peculiarity of metallic lustre.

with the notion of softness, which means the degree of facility with which the plasticity of a metal can be discounted. Thus lead is far softer than silver, and yet the latter is by far the more plastic of the two. The now famous experiments of Tresca (*Comptes Rendus*, lix. 754) show that the plasticity of certain metals at least goes considerably farther than had before been supposed. He operated with lead, copper, silver, iron, and some other metals. Round disks made of these substances were placed in a closely fitting cylindrical cavity drilled in a block of steel, the cavity having a circular aperture of two or four centimetres below. By means of an hydraulic press, applied to a superimposed piston, a pressure of 100,000 kilos was made to act upon the disks, when the metal was seen to "flow" out of the hole like a viscid liquid. In spite of the immense rearrangement of parts there was no breach of continuity. What came out below was a compact cylinder with a rounded bottom, consisting of so many layers superimposed upon one another. Parallel experiments with layers of dough or sand plus some connecting material proved that the particles in all cases moved along the same tracks as would be followed by a flowing cylinder of liquid. Of the better known metals potassium and sodium are the softest; they can be kneaded between the fingers like wax. After these follow first thallium and then lead, the latter being the softest of the metals used in the arts. Among these the softness decreases in about the following order:—lead, pure silver, pure gold, tin, copper, aluminium, platinum, pure iron. As liquidity might be looked upon as the *ne plus ultra* of softness, this is the right place for stating that, while most metals, when heated up to their melting points, pass pretty abruptly from the solid to the liquid state, platinum and iron first assume, and throughout a long range of temperatures retain, a condition of viscous semi-solidity which enables two pieces of them to be "welded" together by pressure into one continuous mass. Potassium and sodium might probably be welded if their surfaces could be kept clear of oxide.

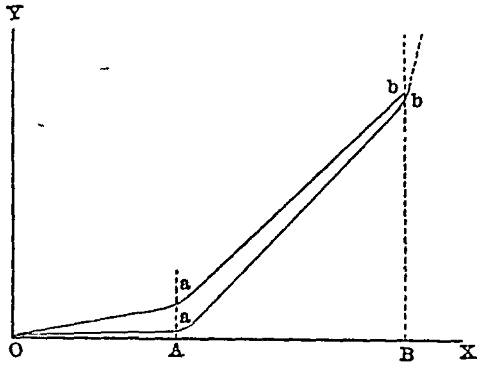
According to Prechtl, the ordinary metals, in regard to the degree of facility or perfection with which they can be hammered flat on the anvil, rolled out into sheet, or drawn into wire, form the following descending series:—

Hammering.	*Rolling into Sheet.*	*Drawing into Wire.*
Lead.	Gold.	Platinum.
Tin.	Silver.	Silver.
Gold.	Copper.	Iron.
Zinc.	Tin.	Copper.
Silver.	Lead	Gold.
Copper.	Zinc.	Zinc.
Platinum.	Platinum.	Tin.
Iron.	Iron.	Lead.

To give an idea of what can be done in this way, it may be stated that gold can be beaten out to leaf of the thickness of $\frac{1}{3800}$ mm.; and that platinum, by judicious work, can be drawn into wire $\frac{1}{200000}$ mm. thick.

By the hardness of a metal we mean the resistance which it offers to the file or to the engraver's tool. Taking it in this sense, it does not necessarily measure, *e.g.*, the resistance of a metal to abrasion by friction. Thus, for instance, 10 per cent. aluminium bronze is scratched by an edge-tool made of ordinary steel as used for knife-blades. And yet it has been found that the sets of needles used for perforating postage stamps last longer if made of aluminium bronze than they do if made of steel.

Elasticity.—All metals are elastic to this extent that a change of form, brought about by stresses not exceeding certain limit values, will disappear on the stress being removed. Strains exceeding the "limit of elasticity" result in permanent deformation or (if sufficiently great) in rupture. Where this limit lies is in no case precisely known. According to Wertheim[1] (who has done more for our knowledge of the subject than any one else) and Hodgkinson, the real law seems to be pretty much as indicated by the two curves on the accompanying diagram, where, in reference to a metallic wire, stretched by an appended weight, the abscissa always means the numerical value P of the weight, the ordinate of the upper curve the total elongation caused by P, the ordinate of the lower curve that part of the elongation which remains when P is removed, so that the piece of the ordinate between the two curves gives the temporary ("elastic") expansion. From P=0 up to a somewhat indefinite point (*a* or A) both curves are nearly straight lines, the lower almost coinciding in its beginning with the axis of abscissæ; from that point onwards these two curves approach each other, and at a short distance from the point of rupture they rapidly converge towards intersection. For any value of P which lies fairly on the safe side of A, we have approximately



$$\lambda = \frac{lP}{q}\epsilon,$$

where λ means the elastic (or substantially the total) expansion, l the length, and q the square section of the wire or cylindrical bar operated upon. The reciprocal of ϵ (viz. $E = 1/\epsilon$) is called the "modulus of elasticity."

Wertheim has determined this constant for a large number of metals and alloys. He used three methods: one was to measure the elongations produced, in a wire of given dimensions, by a succession of charges; the other two consisted in causing a measured bar to give off a musical note by (*a*) longitudinal and (*b*) transversal vibration, and counting the vibrations per second. The following table gives some of his results. Column 2 gives the constant E for millimetre and kilogramme. Hence 1000/E is the elongation in millimetres per metre length per kilo. Column 3 shows the charge causing a permanent elongation of 0·05 mm. per metre,—which, for practical purposes, he takes as giving the limit of elasticity; column 4 gives the breaking strain. Values of E in square brackets [ ] are derived from vibration experiments; the rest from direct measurements of elongations. Numbers in round brackets ( ) do not necessarily refer to the same specimen as the other data.

Name	E.	For Wire of 1 Square mm. Section, Weight (in Kilos) causing	
		Permanent Elongation of $\frac{1}{20000}$.	Breakage.
Lead, drawn	1,803	0·25	2·1
„ annealed	1,727	0·20	1·8
Tin, drawn	[3,923]	0·45	(2·45)
„ annealed	[4,060]	0·20	
Cadmium, drawn	[5,757]		2·24
„ annealed	[4,777]		
Gold, drawn	8,132	13·5	27
„ annealed	5,585	3·0	10
Silver, drawn	7,358	11·3	29
„ annealed	7,141	2·6	16
Zinc, pure, cast in mould	9,021		
Zinc, ordinary, drawn	8,735	0·75	13
„ „ annealed	[9,467]	1·00	
Palladium, drawn	11,759	18	
„ annealed	9,789	under 5	27
Copper, drawn	12,449	12	40
„ annealed	10,519	under 3	30
Platinum wire, medium thickness, drawn	17,004	(26)	
„ „ annealed	15,518	(14)	
Platinum wire, thick, drawn	15,987		34
„ „ annealed	15,622		23
Iron,[2] drawn	20,869	32	61
„ [2] annealed	20,794	under 5	47
Nickel,[3] drawn			$\frac{3}{2}\times 61$
Cobalt,[3] „			2×61
Aluminium[4]	7,040		
Aluminium bronze[4]	10,700		
Brass[5]	8,543		
German silver[6]	10,788		

The above numbers may be assumed to hold for temperatures from 15° to 20° C. Wertheim executed determinations also at other temperatures; but, as his numbers do not appear to reveal the true

[1] *Annales de Chimie et de Physique* [iii.], vol. xii.

[2] From Du Brery. [3] Approximate, by H. St Clair Deville.

[4] From deflexion of hammered bar of 5 mm. thickness, charged in the middle; determined by W. Dittmar.

[5] Composition, $ZnCu_2$ (Wertheim). [6] Composition, $Zn_4Cu_{13}Ni_3$ (Wertheim).

relations between E and temperature, we quote the results of Kohlrausch and Loomis, who found the following relations between the modulus E_0 for 0° C. and the value E_t for $+t°$ C.:—

$$\text{Iron:}\quad E_t = E_0(1 - {\cdot}000483\,t - {\cdot}00000012\,t^2).$$
$$\text{Copper:}\quad E_t = E_0(1 - {\cdot}000572\,t - {\cdot}00000028\,t^2).$$
$$\text{Brass:}\quad E_t = E_0(1 - {\cdot}000485\,t - {\cdot}00000136\,t^2).$$

Thus, for these three metals at least, the value of E diminishes, when temperature increases, at pretty much the same rate per degree of temperature.

Specific Gravity.—This varies in metals from ·594 (lithium) to 22·48 (osmium), and in one and the same species is a function of temperature and of previous physical and mechanical treatment. It has in general one value for the powdery metal as obtained by reduction of the oxide in hydrogen below the melting point of the metal, another for the metal in the state which it assumes spontaneously on freezing, and this latter value again, in general, is modified by hammering, rolling, or wire-drawing, &c. These mechanical operations do not necessarily add to the density; stamping, it is true, does so necessarily, but rolling or drawing occasionally causes a diminution of the density. Thus, for instance, chemically pure iron in the ingot has the specific gravity 7·844; when it is rolled out into thin sheet, the value falls to 7·6; when drawn into thin wire, to 7·75 (Berzelius). The following table gives the specific gravities of all metals (except a few very rare ones) according to the most trustworthy modern determinations. Where special statements are not made, the numbers may be assumed to hold for the ordinary temperature (15° to 17° or 20° C.), referred to water of the same temperature (specific gravity =1) as a standard, and to hold for the natural frozen metal.

Name of Metal.	Specific Gravity.	Authority.
Lithium	·594	Bunsen.
Potassium	·875	Baumhauer.
Sodium	·9735	,,
Rubidium	1·52	Bunsen.
Calcium	1·578	Bunsen and Matthiesen.
Magnesium	1·743	Bunsen.
Cæsium	1·88	Setterberg.
Beryllium	2·1	Debray.
Strontium	2·5	
Aluminium, pure, ingot	2·583 at 4°	Mallet, 1880.
Aluminium, ordinary, hammered	2·67	
Barium	over 4°	Clarke.
Zirconium	4·15	Troost.
Vanadium, powder	5·5	Roscoe.
Gallium	5·9	Lecoq de Boisbaudran.
Lanthanum	6·163	,,
Didymium	6·544	Hillebrandt and Norton.
Cerium	6·728	,, ,,
Antimony	6·715 at 16°	Marchand and Scheerer.
Chromium	6·81	Wöhler.
Zinc, ingot	6·915	Karsten.
,, rolled out	7·2	
Manganese	7·14 to 7·2	Brunner.
Tin, cast	7·29 to 7·299	Various authorities.
,, crystallized by galvanic current from solutions	7·178	W. H. Miller.
Indium	7·42	Richter.
Iron, chemically pure, ingot	7·844	Berzelius.
,, thin sheet	7·6	,,
,, wrought, high quality	7·8 to 7·9	
Nickel, ingot	8·279	Richter.
,, forged	8·666	,,
Cadmium, ingot	8·546	Schröder.
,, hammered	8·667	,,
Cobalt	8·5 to 8·7	
Molybdenum, containing 4 to 5 per cent. of carbon	8·6	Debray.
Copper, native	8·94	
,, cast	8·92	Marchand and Scheerer.
,, wire or thin sheet	8·94 to 8·95	,, ,,
,, electrotype, pure	8·945	Hampe.
Bismuth	9·823 at 12°	Holzmann.
Silver, cast	10·4 to 10·5	,,
,, stamped	10·57	G. Rose.
Lead, very slowly frozen	11·254	Deville.
,, quickly frozen in cold water	11·363	,,
Palladium	11·4 at 22°·5	Deville and Debray.
Thallium	11·86	Crookes.
Rhodium	12·1	Bunsen.
Ruthenium	12·26 at 0°	Deville and Debray.
Mercury, liquid	13·595 at 0°	H. Kopp.
,, solid	14·39 below −40°	
Tungsten, compact, by H_2 from chloride vapour	16·54	Wöhler, 1855.
,, as reduced by hydrogen, powder	19·13	Roscoe.
Uranium	18·33	Péligot, 1868.
Gold, ingot	19·265 at 13°	Matthiesen.
,, stamped	19·31 to 19·34	G. Rose.
,, powder, precipitated by ferrous sulphate	19·55 to 19·72	,,
Platinum, pure	21·46	
Iridium	22·40	
Osmium	22·477	Deville and Debray, 1876.

Thermic Properties.—*The specific heats of most metals* have been determined very carefully by Regnault. The general result is that, conformably with Dulong and Petit's law, the "atomic heats" all come to very nearly the same value (of about 6·4); *i.e.*, atomic weight by specific heat=6·4. Thus we have for silver by theory 6·4/108=·0593, and by experiment ·0570 for 10° to 100° C.

The expansion by heat varies greatly. The following table gives the linear expansions from 0° to 100° C. according to Fizeau (*Comptes Rendus*, lxviii. 1125), the length at 0° being taken as unity.

Name of Metal.	Expansion 0° to 100°.
Platinum, cast	·000 907
Gold, cast	·001 451
Silver, cast	·001 936
Copper, native, from Lake Superior	·001 708
Copper, artificial	·001 869
Iron, soft, as used for electromagnets	·001 228
,, reduced by hydrogen and compressed	·001 208
Cast steel, English annealed	·001 110
Bismuth, in the direction of the axis	·001 642
,, at right angles to axis	·001 239
,, mean expansion, calculated	·001 374
Tin, of Malacca, compressed powder	·002 269
Lead, cast	·002 948
Zinc, distilled, compressed powder	·002 905
Cadmium, distilled, compressed powder	·003 102
Aluminium, cast	·002 336
Brass (71·5 per cent. copper, 28·5 per cent. zinc)	·001 879
Bronze (86·3 per cent. copper, 9·7 per cent. tin, 4·0 per cent. zinc).	·001 802

The coefficient of expansion is constant for such metals only as crystallize in the regular system; the others expand differently in the directions of the different axes. To eliminate this source of uncertainty these metals were employed as compressed powders. The cubical expansion of mercury from 0° to 100° C. is ·018153 $=\frac{1}{55{\cdot}087}$ (Regnault).

Fusibility and Volatility.—The fusibility in different metals is very different, as shown by the following table, which, besides including all the fusing points (in degrees C.) of metals which have been determined numerically, indicates those of a selection of other metals by the positions assigned to them in the table. Of the temperatures given, those above (say) 500° C. must be looked upon as rough approximations.

Name of Metal.	Fusing Point.	Authority.
Mercury	−38·8	B. Stewart.
Cæsium	+26 to 27	Setterberg.
Gallium	30·1	L. de Boisbaudran.
Rubidium	38·5	Bunsen.
Potassium	62·5	,,
Sodium	95·5	,,
Lithium	180·0	?
Indium	176	Richter (?)
Tin	228	Rudberg.
Bismuth	264	,,
Thallium	290	Lamy.
Cadmium	320	Rudberg.
Lead	325	,,
Antimony	425	
Zinc	415	Person.
,,	412	Daniell.
Incipient Red Heat	525	Pouillet.
Magnesium		
Aluminium		
Cherry Red Heat	700	Pouillet.
Silver	1,040	Becquerel.
Gold	1,100	
Yellow Heat	1,100	Pouillet.
Copper	1,200	
Iron, wrought	1,300 to 1,400	
,, chemically pure	higher	
Cobalt	1,400	
Nickel	1,600	
Uranium	?	
Dazzling White Heat	1,500 to 1,600	Pouillet.
Palladium is barely fusible at the highest wind-furnace heat. The following melt only in the oxyhydrogen flame:—		
Platinum	2,000	
Iridium		
Rhodium		
Ruthenium		
Max. Temp. of Oxyhydrogen Flame	2,870	Bunsen.[1]
Osmium does not melt at 2,870°, *i.e.*, is as yet infusible.		

Of the volatility of metals we have little precise knowledge; only the following boiling points are known numerically:—

Name of Metal.	Boiling Point.	Authority.
Mercury	357·3	Regnault.
Cadmium	860	Deville and Troost.
Zinc	1,040	,, ,,
Potassium	below 1,040	Dewar and Dittmar.
Sodium	above 1,040	,, ,,

For practical purposes the volatility of metals may be stated as follows:—

1. Distillable below redness: mercury.
2. Distillable at red heats: *cadmium, alkali metals, zinc, magnesium.*
3. Volatilized more or less readily when heated beyond their fusing points in open crucibles: antimony (very readily), lead, bismuth, tin, silver.

[1] Bunsen, *Jahresb. f. Chem.*, 1867, p. 41; *Phil. Mag.*, xxxiv. 489.

4. Barely so: gold, (copper).
5. Practically non-volatile: (copper), iron, nickel, cobalt, aluminium; also lithium, barium, strontium, and calcium.

In the oxyhydrogen flame silver boils, forming a blue vapour, while platinum volatilizes slowly, and osmium, though infusible, very readily.

Latent Heats of Liquefaction—Of these we know little. The following numbers are due to Person—ice, it may be stated, being 80.

Metal.	Latent Heat.	Metal.	Latent Heat.
Mercury	2·82	Cadmium	13·6
Lead	5·37	Silver	21·1
Bismuth	12·4	Zinc	28·1

Of the latent heats of vaporization only that of mercury has been determined,—by Marignac, who found it to be 103 to 106 units.

Conductivity.—Conductivity, whether thermic or electric, is very differently developed in different metals; and, as an exact knowledge of these conductivities is of great scientific and practical importance, much attention has been given to their numerical determination. The following are the modes in which the two conductivities have been defined as quantities.

1. *Thermic.*—Imagine one side (I) of a metallic plate, D units thick, to be kept at the constant temperature t_1, the other (II) at t_2. After a sufficient time each point between I and II will be at a constant intermediate temperature, and in every unit of time a constant quantity Q of heat will pass from any circumscribed area S on I to the opposite area S on II, according to the equation

$$Q = l\frac{S(t_1-t_2)}{D}.$$

l is called the (internal) conductivity of the metal the plate is made of. It is, strictly speaking, a function of t_1 and t_2; but within a given small interval of temperatures it may be taken as a constant.

2. *Electric.*—When a given constant battery is closed successively by different wires of the same sort, then, according to experience, the strength I of the current (as measured for instance by the heat-equivalent of the electricity flowing through the circuit in unit of time) is in accordance with the equation

$$A/I = 1 + rl/s,$$

where l is the length and s the square section of the wire, while A is a constant which, for our purpose, need not be defined in regard to its physical meaning; r measures the specific resistance of the particular metal. Supposing a certain silver wire on the one hand and a certain copper wire on the other, when substituted for each other, to produce currents of the same strength, we have

$$r_1 l_1/s_1 = r_2 l_2/s_2,$$

whence

$$r_1/r_2 = s_1 l_2/(s_2 l_1) = k$$

where k is the computed value of the ratio on the right-hand side. Hence, taking r_2, the resistance of copper, as unity, we have $r_1 = k$, *i.e.*, k gives us the specific resistance of silver, that of copper being taken = 1. In this relative manner resistances are usually measured, silver generally being taken as the standard of comparison. Supposing the relative resistance of a metal to be R, the reciprocal 1/R is called its "electric conductivity." For the same metal R varies with the temperature, the higher temperature corresponding to the higher resistance. The following table gives the electric conductivities of a number of metals as determined by Matthiesen, and the relative internal thermic conductivities of (nominally) the same metals as determined by Wiedemann and Franz, with rods about 5 mm. thick, of which one end was kept at 100° C., the rest of the rod in a "vacuum" (of 5 mm. tension) at 12° C. Matthiesen's results, except in the two cases noted, are from his memoir in *Pogg. Ann.*, 1858, ciii. 428.

Metals.	Relative Conductivities.	
	Electric.	Thermic.
Copper, commercial, No. 3	·774 at 18·8°	
" " No. 2	·721 " 22·6	
" chemically pure, hard drawn	·93[1]	
Copper		·748
Gold, pure	·552 " 21·8	·548
" absolutely pure	·73[1] " 19·0	
Brass		·25
Tin, pure	·115 " 21·0	·154
Pianoforte wire	·144 " 20·4	
Iron rod		·101
Steel		·103
Lead, pure	·0777 " 17·3	·079
Platinum	·105 " 20·7	·094
German silver	·0767 " 18·7	·073
Bismuth	·0119 " 13·8	
Aluminium	·196 " 19·6	
Mercury	·0163 " 22·8	
Silver, pure	1·000 " 0	1·000

[1] Published in 1860, and declared by Matthiesen to be more exact than the old numbers.

Going by Matthiesen's old numbers, we find them to agree fairly with Wiedemann and Franz's thermic conductivities, which supports an obvious and pretty generally received proposition. Matthiesen's new numbers for gold and copper, however, destroy the harmony.

Magnetic Properties.—Iron, nickel, and cobalt are the only metals which are attracted by the magnet and can become magnets themselves. But in regard to their power of retaining their magnetism none of them comes at all up to the compound metal steel. See MAGNETISM.

Chemical Changes.

The chemical changes which metals are liable to may be classified according to the loss of metallicity involved in them. We will adopt this principle and begin with the action of metals on metals, which, as experience shows, always leads to the formation of truly metallic compounds.

Any two or more metals when mixed together in the liquid state unite chemically, or at least molecularly, in this sense that, although the mixture, on standing (hot), may separate into layers, each layer is a homogeneous solution or "alloy" of, in general, all the components in one another. With binary combinations the following two cases may present themselves:—(1) the two metals mix permanently in any proportion; or (2) either of the two metals refuses to take up more than a certain limit-proportion of the other; hence a random mixture of the two metals will, in general, part into two layers,—one a solution of A in B, the other a solution of B in A. The first case presents itself very frequently; it holds, for instance, for gold and silver, gold and copper, copper and silver, lead and tin, and any alloy of these two and bismuth. Many other cases might be quoted. A good example of the second case is lead and zinc, either of which dissolves only a very small percentage of the other. In the preparation of an alloy we need not start with the components in the liquid state; the several metals need only be heated together in the same crucible when, in general, the liquid of the more readily fusible part dissolves the more refractory components at temperatures far below their fusing points. Molten lead, for instance, as many a tyro in chemical analysis has come to learn to his cost, readily runs through a platinum crucible at little more than its own fusing point.

A homogeneous liquid alloy, when solidified suddenly, say by pouring it drop by drop into cold water, necessarily yields an equally homogeneous solid. But it may not be so when it is allowed to freeze gradually. If, in this case, we allow the process to go a certain way, and then pour off the still liquid portion, the frozen part generally presents itself in the shape of more or less distinct crystals; whether this happens or not, the rule is that its composition differs from that of the mother liquor, and consequently from that of the original alloy. This phenomenon of "liquation," as it is called, is occasionally utilized in metallurgy for the approximate separation of metals from one another;[2] but in the manipulation of alloys made to be used as such it may prove very inconvenient. It does so, for instance, in the case of the copper-silver alloy which our coins are made of; in a large ingot of such sterling silver the core may contain as much as 0·3 per-cent. of silver more than the outer shell.

The existence of crystallized alloys, as the phenomenon of liquation generally, strongly suggests the idea that alloys generally are mixtures, not of their elementary components, but of chemical compounds of these elements with one another, associated possibly with uncombined remnants of these. This notion is strongly supported by the fact that the formation of many alloys involves an obvious evolution of heat and a decided modification in what one would presume to be the properties of the corresponding

[2] A good illustration is afforded by the process of Pattinson as used for concentrating the silver in argentiferous lead. See LEAD.

mixture. The case of sodium amalgam may be quoted as a forcible illustration. What goes by this name in laboratories is an alloy of two to three parts of sodium with one hundred parts of mercury, which is easily produced by forcing the two components into contact with each other by means of a mortar and pestle, when they unite, with deflagration, into an alloy which after cooling assumes the form of a grey, hard, brittle solid, although mercury is a liquid, and sodium, though a solid, is softer than wax. Similar evidence of chemical action we have in the cases of brass (copper and zinc), bronze (copper and tin), aluminium bronze (copper and aluminium), and in many others that might be quoted. There are indeed a good many alloys the formation of which is not accompanied by any obvious evolution of heat or any very marked change in the mean properties of the components. But in the absence of all precise thermic researches on the subject we are not in a position to assert the absence of chemical action in any case. Indeed our knowledge of the proximate composition of alloys is in the highest degree indefinite—we do not even know of a single composite metal which has been really proved to be an unitary compound, and hence the important problem of the relation in alloys between properties and composition must be attacked on a purely empirical basis. What has been done in this direction is shortly summarized in the following paragraphs.

Colour.—Most metals are white or grey; so are the alloys of these metals with one another. Gold alloys generally exhibit something like the shade of yellow which one would expect from their composition; its amalgams, however, are all white, not yellow. Copper shows little tendency to impart its characteristic red colour to its alloys with white or grey metals. Thus, for instance, the silver alloy up to about 30 per cent. of copper exhibits an almost pure white colour. The alloys of copper with zinc (brass) or tin (bronze) are reddish-yellow when the copper predominates largely. As the proportion of white metal increases, the colour passes successively into dark yellow, pale yellow, and ultimately into white. Aluminium bronze, containing from 5 to 10 per cent. of aluminium, is golden-yellow.

Plasticity.—This quality is most highly developed in certain pure metals, notably in gold, platinum, silver, and copper. Of platinum alloys little is known. The other three, on uniting with one another, substantially retain their plasticities, but the addition of any metal outside the group leads to deterioration. Thus, for instance, according to Karsten, copper, by being alloyed with as little as 0·6 per cent. of zinc, loses its capability of being forged at a red heat; it cracks under the hammer. Antimony or arsenic to the extent of 0·15 per cent. renders it unfit for being rolled into thin sheet or drawn out into fine wire, and makes it brittle in the heat; 0·1 per cent. of lead prohibits its conversion into leaf.

Hardness, Elasticity, Tensile Strength.—In reference to these qualities, we shall confine ourselves to some very striking changes for the better which the metals (1) gold, (2) silver, (3) copper suffer when alloyed with moderate proportions (10 per cent. or so) of (1) copper, (2) copper, (3) tin, zinc, or aluminium respectively. Any of these five combinations leads to a considerable increase in the three qualities named, although these are by no means highly developed in the added metals; most strikingly it does so in the case of aluminium bronze (copper and aluminium), which is so hard as to be very difficult to file, and is said to be equal in tensile strength to wrought iron. To illustrate this we give in the following table, after Matthiesen, the breaking strains of double wires, No. 23 gauge, in lb avoirdupois, for certain alloys on the one hand and their components on the other.

Separate Metals.		*Alloys.*	
Copper	25–30	Gun metal, 12 per cent. of tin	80–90
Tin	less than 7		
Copper	25–30	Standard (22 carat) gold	70–75
Gold	20–25		
Silver	40–45	Alloy, $\frac{2}{3}$ of silver, $\frac{1}{3}$ of platinum	75–80
Platinum	45–50		

Specific Gravity.—This subject has been extensively investigated by Matthiesen, Calvert and Johnson, Kuppfer, and others. In discussing the results it is convenient to compare the values (S) found with the values (S_0) calculated on the assumption that the volume of the alloy is equal to the sum of the volumes of the components. Let p_1, p_2, p_3...stand for the relative weights of the components, P for their joint weight, S_1, S_2, S_3...for their specific gravities, and we have

$$\frac{P}{S_0}=\frac{p_1}{S_1}+\frac{p_2}{S_2}+\dots$$

where the expression on the right hand obviously means the conjoint volume V_0 of the components; but the actual volume of the alloy formed by their union is, in general, $V=V_0(1+e)$, where e means the expansion (or, when negative, the contraction) of unit-volume of mixture. Hence the real value

$$S=S_0/(1+e)\,,$$

whence

$$e=(S_0-S)/S.$$

Matthiesen's investigation (*Pogg. Annalen* for 1860, vol. cx. p. 21) extends over a large number of binary alloys derived from the metals named in the following table. He naturally began by procuring pure specimens of these metals and determining their specific gravities. The results (each the mean of a number of determinations) were as follows:—

Name.	Specific Gravity S at t° C.	t	Adopted Atomic Weight.
Antimony	6·713	14·3°	122·3
Tin	7·294	12·8	118
Cadmium	8·655	10·5	112
Bismuth	9·823	12·3	208
Silver	10·468	13·2	108
Lead	11·376	13·5	207·4
Mercury	13·573	14·5	200
Gold	19·265	12·8	197

In these, as in all the subsequent determinations for the alloys, the weighings were reduced to the vacuum, and the values for S referred to water at 4° C. as unity. From eight metals twenty-eight different kinds of binary alloys can be produced; of these twenty-eight combinations eighteen were selected; in each case the two components were fused together in a variety of properly chosen atomic proportions, and the specific gravities of these alloys were determined. The net results are summarized in the following table, which, for each combination A, B, in the first two columns gives the composition in multiplies of the "atomic-weights" given in the table just quoted, while column 3 gives the values of e as calculated by the writer from Matthiesen's numbers for S_0 and S. Hence, for example, in the accompanying entries the first line shows that the union into an alloy of twice 118 parts of tin and once 197 parts of gold involves an expansion from 1 volume into 1·004; the second that the union of once 118 parts of tin with four times 197 parts of gold involves a contraction from 1 volume into 1 − ·028.

Tin and Gold.

Sn	A	e
2	1	+·004
1	4	−·028

Antimony and Tin.

Sb	Sn	e
12 to 8	1	+·002
4−2	1	+·006
1	1 to 2	+·008
1	3 to 10	+·005
1	20 to 100	0

Antimony, Bismuth.

Sb	Bi	e
2	1 to 12	0

Antimony, Lead.

Sb	Pb	e
2	1	+·008
1	1	+·006
2	1	0
3	1	+·0067
5−25	1	0

Tin, Cadmium.

Sn	Cd	e
6	1	+·004
4	1	+·005
2	1 to 8	0
2	12	−·001

Tin, Bismuth.

Sn	Bi	e
22	1	0
4	1	−·002
3−1	1	−·005
1	2	−·005
1	4 to 60	0

Tin, Silver.

Sn	Ag	e
18	1	−·002
9	1	−·006
6	1	−·008
3	1	−·013
2	1	−·019
1	1	−·024
1	2	−·047
1	4	−·038

Tin, Gold.

Sn	Au	e
50	1	0
15−6	1	−·002
4−2·5	1	+·002
2	1	+·004
3	2	+·008
1	1	+·012
1	2	−·015
1	4	−·028

Tin, Lead.

Sn	Pb	e
6	1	+·003
4	1	+·002
2	1	0
1	1	+·0015
1	2−4	+·005
1	6	+·004

Cadmium, Bismuth.

Cd	Bi	e
3	1−36	0

Cadmium, Lead.

Cd	Pb	e
6	1−36	0 to ·0025

Bismuth, Silver.

Bi	Ag	e
200−2	1	0 to +·002
1	1	−·003
1	2	−·006
1	4	−·007

Bismuth, Gold.

Bi	Au	e
90	1	0
40	1	0
20	1	−·003
8	1	−·009
4	1	−·017
2	1	−·035
1	1	−·039
1	2	−·026

Lead, Gold.

Pb	Au	e
10	1	−·004
5	1	−·009
4	1	−·008
3	1	−·009
2	1	−·016
1	1	−·018
1	2	−·004
1	4	−·011

Bismuth, Lead.		
Bi	Pb	e
60—20	1	0
16	1	—·003
12	1	—·005
8	1	—·007
4	1	—·014
2	1	—·021
1	1	—·040
1	2	—·031
1	3	—·020
1	4	—·015
1	5	—·010
1	12	—·004
1	50	0

Lead, Silver.		
Pb	Ag	e
1	4	—·005
1	2	—·003
1	1	0
2	1	+·003
4	1	+·006
10	1	+·004
25		+·002

Gold, Silver.		
Au	Ag	e
1	6	—·004
1	4	—·004
1	2	—·004
1	1	—·002
2	1	—·0025
4	1	—·0027
6	1	—·0024

Mercury, Tin.		
Hg	Sn	e
1	2	—·009
1	1	—·005
2	1	—·007

Mercury, Lead.		
Hg	Pb	e
1	2	+·002
1	1	—·010
2	1	—·016

To make these numbers trustworthy it would be necessary to determine their probable errors; and this Matthiesen has not done. It would appear that any value of e from 0 to (say) $\pm$ ·002 counts for nothing, and anything up to ·004 certainly must be taken as not proving much either way. If this is correct, then

(1) No contraction or expansion is proved in the cases Sb, Bi; Cd, Bi; Cd, Pb; Au, Ag;

(2) A contraction (from 0·5 to 4·7 per cent.) is proved for Sn, Ag; Bi, Ag; Bi, Au; Pb, Au; Pb, Bi; Hg, Sn; Hg, Pb; Sn, Bi (?); Au, Ag (?);

(3) An expansion (from ·5 to 0·8 per cent.) is proved for Sb, Sn; Sb, Pb; Sn, Cd (?); Sn, Pb (?); certain cases of Sn, Au and Pb, Ag;

(4) In the two series Sn, Au and Pb, Ag, there are cases both of expansion and of contraction.

Thermic and Electric Properties.—The specific heat of an alloy, so far as we know, is always in approximate accordance with Dulong and Petit's law. Thus the specific heat of Cu_5Al_1 is

$$\frac{(5+1)\times 6{\cdot}4}{5\times 63{\cdot}5+1\times 27},$$

with about the same degree of correctness as the "constant" 6·4 can claim for itself.

Expansion.—Matthiesen, from numerous determinations made with alloys and their components, concludes that the expansion of an alloy (from 0° to 100° C.) is nearly equal to the sum of the expansions of its components. Supposing, for instance, one volume of gold to expand (from 0° to t) by α, and one volume of silver by β; then an alloy of four volumes of gold and three volumes of silver expands by $(4\alpha+3\beta)/7$ per unit.

Fusibility.—In the case of an alloy the melting-point and the freezing-point are, in general, separated by a greater or less interval of temperature, and the latter in itself may have two values as shown by Rudberg, who found that when a fused alloy of tin and lead is allowed to freeze the thermometer becomes stationary at two successive points, as shown in the following table, where x means the number of atomic weights of tin united with y of lead in the given case, and the temperatures are in centigrade degrees.

x	0	1	1	3	4	12	∞
y	∞	3	1	1	1	1	0
First point	(325°)	280°	240°	187°	187°	210°	(228°)
Second point	(325°)	187°	187°	187°	187°	187°	(228°)

We see that the first point varies with, while the second, within the range of the experiments, proved independent of, the proportion in which the two metals are united.

The melting-point of many alloys lies below that of even the most fusible component, as illustrated in the following tables, where the numbers mean parts by weight.

Tin and Lead (Rudberg).

Per cent. of Tin.	Per cent. of Lead.	Melting-point.
100	0	228°
0	100	325
74	26	194
63	37	186
53	47	196
36	64	241
16	84	289

Name of Alloy.	Tin.	Lead.	Bismuth.	Cadmium.	Melting-point.
Newton's	3	2	5	0	100°
Rose's	3	8	8	0	95
Erman's	1	1	2	0	93·7
Wood's	2	4	7	1	70
(Cadmium)	0	0	0	1	(320)

All these alloys melt in boiling water.

The electric conductivity of alloys *qua* alloys has been investigated by Matthiesen. He confined himself to binary alloys derived from a certain set of elementary metals. The main results of his researches are given in ELECTRICITY, vol. viii. p. 51. For the practical electrician it is important to observe how very much the conductivity of copper is impaired by very minute admixtures even of metals that are good conductors, and also by non-metallic contamination, especially with oxygen (present as Cu_2O).

Metallic Substances Produced by the Union of Metals with Small Proportions of Non-Metallic Elements.

Hydrogen, as was shown by Graham, is capable of uniting with (always very large proportions of) certain metals, notably with palladium, into metal-like compounds. But those hydrogen alloys, being devoid of metallurgic interest, fall better under the heading PALLADIUM.

Oxygen.—Mercury and copper (perhaps also other metals) are capable of dissolving their own oxides with formation of alloys. Mercury, by doing so, becomes viscid and unfit for its ordinary applications. Copper, when pure to start with, suffers considerable deterioration in plasticity. But the presence of moderate proportions of cuprous oxide has been found to correct the evil influence of small contaminations by arsenic, antimony, lead, and other foreign metals. Most commercial coppers owe their good qualities to this compensating influence.

Arsenic combines readily with all metals into true arsenides, which latter, in general, are soluble in the metal itself. The presence in a metal of even small proportions of arsenide generally leads to considerable deterioration in mechanical qualities.

Phosphorus.—The remark just made might be said to hold for phosphorus were it not for the existence of what is called "phosphorus-bronze," an alloy of copper with phosphorus (*i.e.*, its own phosphide), which possesses valuable properties. According to Abel, the most favourable effect is produced by from 1 to $1\frac{1}{2}$ per cent. of phosphorus. Such an alloy can be cast like ordinary bronze, but excels the latter in hardness, elasticity, toughness, and tensile strength. See PHOSPHORUS.

Carbon.—Most metals when in a molten state are capable of dissolving at least small proportions of carbon, which, in general, leads to a deterioration in metallicity, except in the case of iron, which by the addition of small percentages of carbon gains in elasticity and tensile strength with little loss of plasticity (see IRON).

Silicon, so far as we know, behaves to metals pretty much like carbon, but our knowledge of facts is limited. What is known as "cast iron" is essentially an alloy of iron proper with 2 to 6 per cent. of carbon and more or less of silicon (see IRON). Alloys of copper and silicon were prepared by Deville in 1863. The alloy with 12 per cent. of silicon is white, hard, and brittle. When diluted down to 4·8 per cent., it assumes the colour and fusibility of bronze, but, unlike it, is tenacious and ductile like iron.

Action of the More Ordinary Chemical Agents on Simple Metals.

To avoid repetition, let us state beforehand that the metals to be referred to are always understood to be given in the compact (frozen) condition, and that, wherever a series of metals are enumerated as being similarly attacked, the degree of readiness in the action is (so far as our knowledge goes) indicated by the order in which the several members are named,—the more readily changed metal always standing first.

Water, at ordinary or slightly elevated temperatures, is decomposed more or less readily, with evolution of hydrogen gas and formation of a basic hydrate, by (1) potassium (formation of KHO), sodium (NaHO), lithium (LiOH), barium, strontium, calcium (BaO_2H_2, &c.); (2) magnesium, zinc, manganese (MgO_2H_2, &c.).

In the case of group 1 the action is more or less violent, and the hydroxides formed are soluble in water and very

strongly basylous; metals of group 2 are only slowly attacked, with formation of relatively feebly basylous and practically insoluble hydrates. Disregarding the rarer elements (as we propose to do in this section), the metals not named so far may be said to be proof against the action of pure water in the absence of free oxygen (air).

By the conjoint action of water and air, thallium, lead, bismuth are oxidized, with formation of more or less sparingly soluble hydrates ($ThHO$, PbO_2H_2, BiO_3H_3), which, in the presence of carbonic acid, pass into still less soluble basic carbonates.

Iron, as everybody knows, when exposed to moisture and air, "rusts," that is, undergoes gradual conversion into a brown ferric hydrate, $Fe_2O_3xH_2O$; but this process never takes place in the absence of air, and it is questionable whether it ever sets in in the absence of carbonic acid. What is known is that iron never rusts in solutions of caustic alkalies or lime (which reagents preclude the presence of free carbonic acid), while it does so readily in ordinary moist air containing CO_2. When once started the process proceeds with increasing rapidity, the ferric hydrate produced acting as a carrier of oxygen; it gives up part of its oxygen to the adjoining metal, being itself reduced to (perhaps) Fe_3O_4, which latter again absorbs oxygen from the air to become ferric hydrate and so on (Kuhlmann).

Copper, in the present connexion, is intermediate between iron and the following group of metals.

Mercury, if pure, and all the "noble" metals (silver, gold, platinum, and platinum-metals), are absolutely proof against water even in the presence of oxygen and carbonic acid.

The metals grouped together above under 1 and 2 act on steam pretty much as they do on liquid water. Of the rest, the following are readily oxidized by steam at a red heat, with formation of hydrogen gas,—zinc, iron, cadmium, cobalt, nickel, tin. Bismuth is similarly attacked, but slowly, at a white heat. Aluminium is barely affected even at a white heat, if it is pure; the ordinary impure metal is liable to be very readily oxidized.

Aqueous Sulphuric or Hydrochloric Acid, of course, readily dissolves groups 1 and 2, with evolution of hydrogen and formation of chlorides or sulphates. The same holds for the following group (A):—[manganese, zinc, magnesium] iron, aluminium, cobalt, nickel, cadmium. Tin dissolves readily in strong hot hydrochloric acid as $SnCl_2$; aqueous vitriol does not act on it appreciably in the cold; at 150° it attacks it more or less quickly, according to the strength of the acid, with evolution of sulphuretted hydrogen or, when the acid is stronger, of sulphurous acid gas and deposition of sulphur (Calvert and Johnson). A group (B), comprising copper, are, substantially, attacked only in the presence of oxygen or air. Lead, in sufficiently dilute acid, or in stronger acid if not too hot, remains unchanged. A group (C) may be formed of mercury, silver, gold, and platinum, which are not touched by either aqueous acid in any circumstances.

Hot (concentrated) oil of vitriol does not attack gold, platinum, and platinum-metals generally; all other metals (including even silver) are converted into sulphates, with evolution of sulphurous acid. In the case of iron, ferric sulphate, $Fe_2(SO_4)_3$, is produced; tin yields a somewhat indefinite sulphate of its binoxide SnO_2.

Nitric Acid (Aqueous).—Gold, platinum, iridium, and rhodium only are proof against the action of this powerful oxidizer. Tin and antimony (also arsenic) are converted by it (ultimately) into hydrates of their highest oxides SnO_2, Sb_2O_5 (As_2O_5),—the oxides of tin and antimony being insoluble in water and in the acid itself. All other metals, including palladium, are dissolved as nitrates, the oxidizing part of the reagent being generally reduced to nitric oxide, NO, or sometimes to N_2O_3 or N_2O_4. Iron, zinc, cadmium, also tin under certain conditions, reduce the dilute acid, partially at least, to nitrous oxide, N_2O, or nitrate of ammonia, $NH_4.NO_3 = N_2O + 2H_2O$.

Aqua Regia, a mixture of nitric and hydrochloric acids, converts all metals (even gold, the "king of metals," whence the name) into chlorides, except only rhodium, iridium, and ruthenium, which, when pure, are not attacked.

Caustic Alkalies.—Of metals not decomposing liquid pure water, only a few dissolve in aqueous caustic potash or soda, with evolution of hydrogen. The most important of these are aluminium and zinc, which are converted into aluminate, $Al_2O_33(K_2$ or $Na_2)O$, and zincate, $ZnO.RHO$, where $R = K$ or Na respectively. But of the rest the majority, when treated with boiling sufficiently strong alkali, are attacked at least superficially; of ordinary metals only gold, platinum, and silver are perfectly proof against the reagents under consideration, and these accordingly are used preferably for the construction of vessels intended for analytical operations involving the use of aqueous caustic alkalies. For preparative purposes iron is universally employed and works well; but it is not available analytically, because a superficial oxidation of the empty part of the vessel (by the water and air) cannot be prevented. According to the writer's experience basins made of pure malleable nickel are free from this drawback; they work as well as platinum, and rather better than silver ones do. There is hardly a single metal which holds out against the alkalies themselves when in the state of fiery fusion; even platinum is most violently attacked. In chemical laboratories fusions with caustic alkalies are always effected in vessels made of gold or silver, these metals holding out fairly well even in the presence of air. Gold is the better of the two. Iron, which stands so well against aqueous alkalies, is most violently attacked by the fused reagents. Yet tons of caustic soda are fused daily in chemical works in iron pots without thereby suffering contamination, which seems to show that (clean) iron, like gold and silver, is attacked only by the conjoint action of fused alkali and air, the influence of the latter being of course minimized in large-scale operations.

Oxygen or Air.—The noble metals (from silver upwards) do not combine directly with oxygen given as oxygen gas (O_2), although, like silver, they may absorb this gas largely when in the fused condition, and may not be proof against ozone, O_3. Mercury, within a certain range of temperatures situated close to its boiling point, combines slowly with oxygen into the red oxide, which, however, breaks up again at higher temperatures. All other metals, when heated in oxygen or air, are converted, more or less readily, into stable oxides. Potassium, for example, yields peroxide, K_2O_2 or K_2O_4; sodium gives Na_2O_2; the barium-group metals, as well as magnesium, cadmium, zinc, lead, copper, are converted into their monoxides MeO. Bismuth and antimony give (the latter very readily) sesquioxide (Bi_2O_3 and Sb_2O_3, the latter being capable of passing into Sb_2O_4). Aluminium, when pure and kept out of contact with siliceous matter, is only oxidized at a white heat, and then very slowly, into alumina, Al_2O_3. Tin, at high temperatures, passes slowly into binoxide, SnO_2.

Sulphur.—Amongst the better known metals, gold and aluminium are the only ones which, when heated with sulphur or in sulphur vapour, remain unchanged. All the rest, under these circumstances, are converted into sulphides. The metals of the alkalies and alkaline earths, also magnesium, burn in sulphur-vapour as they do in oxygen. Of the heavy meals, copper is the one which exhibits by far the greatest avidity for sulphur, its subsulphide Cu_2S being the stablest of all heavy metallic sulphides in opposition to dry reactions. See METALLURGY.

Chlorine.—All metals, when treated with chlorine gas at the proper temperatures, pass into chlorides. In some cases the chlorine is taken up in two instalments, a lower chloride being produced first, to pass ultimately into a higher chloride. Iron, for instance, is converted first into $FeCl_2$, ultimately into Fe_2Cl_6, which practically means a mixture of the two chlorides, or pure Fe_2Cl_6 as a final product. Of the several products, the chlorides of gold and platinum ($AuCl_3$ and $PtCl_4$) are the only ones which when heated beyond their temperature of formation dissociate into metal and chlorine. The ultimate chlorination product of copper, $CuCl_2$, when heated to redness, decomposes into the lower chloride, Cu_2Cl_2, and chlorine. All the rest, when heated by themselves, volatilize, some at lower, others at higher temperatures.

Of the several individual chlorides, the following are liquids or solids, volatile enough to be distilled from out of glass vessels:—$AsCl_3$, $SbCl_3$, $SnCl_4$, $BiCl_3$, $HgCl_2$, the chlorides of arsenic, antimony, tin, bismuth, mercury respectively. The following are readily volatilized in a current of chlorine, at a red heat:—Al_2Cl_6, Cr_2Cl_6, Fe_2Cl_6, the chlorides of aluminium, chromium, iron. The following, though volatile at higher temperatures, are not volatilized at dull redness:—KCl, $NaCl$, $LiCl$, $NiCl_2$, $CoCl_2$, $MnCl_2$, $ZnCl_2$, $MgCl_2$, $PbCl_2$, $AgCl$, the chlorides of potassium, sodium, lithium, nickel, cobalt, manganese, zinc, magnesium, lead, silver. Somewhat less volatile than the last-named group are the chlorides (MCl_2) of barium, strontium, and calcium.

Metallic chlorides, as a class, are readily soluble in water. The following are the most important exceptions:—chloride of silver, $AgCl$, and subchloride of mercury, Hg_2Cl_2, are absolutely insoluble; chloride of lead, $PbCl_2$, and subchloride of copper, Cu_2Cl_2, are very sparingly soluble in water. The chlorides $AsCl_3$, $SbCl_3$, $BiCl_3$, are at once decomposed by (liquid) water, with formation of oxide (As_2O_3) or oxychlorides ($SbClO$, $BiClO$) and hydrochloric acid. The chlorides $MgCl_2$, Al_2Cl_6, Cr_2Cl_6, Fe_2Cl_6 suffer a similar decomposition when evaporated with water in the heat. The same holds in a limited sense for $ZnCl_2$, $CoCl_2$, $NiCl_2$, and even $CaCl_2$. All chlorides, except those of silver and mercury (and, of course, those of gold and platinum), are oxidized by steam at high temperatures, with elimination of hydrochloric acid.

The above statements concerning the volatilities and solubilities of metallic chlorides form the basis of a number of important analytical methods for the separation of the respective metals.

For the characters of metals as chemical elements the reader is referred to the article CHEMISTRY and to the special articles on the different metals. (W. D.)

METAL-WORK. Among the many stages in the development of primeval man, none can have been of greater moment in his struggle for existence than the discovery of the metals, and the means of working them. The names generally given to the three prehistoric periods of man's life on the earth—the Stone, the Bronze, and the Iron age—imply the vast importance of the progressive steps from the flint knife to the bronze celt, and lastly to the keen-edged elastic iron weapon or tool. The length of time during which each of these ages lasted must of course have been different in every country and race in the world. The Digger Indians of South California have even now not progressed beyond the Stone Age; while some of the tribes of Central Africa are acquainted with the use of copper and bronze, though they are unable to smelt or work iron.

The metals chiefly used have been gold, silver, copper and tin (the last two generally mixed, forming an alloy called bronze), iron, and lead. The peculiarities of these various metals have naturally marked out each of them for special uses and methods of treatment. The durability and the extraordinary ductility and pliancy of gold, its power of being subdivided, drawn out, or flattened into wire or leaf of almost infinite fineness, have led to its being used for works where great minuteness and delicacy of execution were required; while its beauty and rarity have, for the most part, limited its use to objects of adornment and luxury, as distinct from those of utility. In a lesser degree most of the qualities of gold are shared by silver, and consequently the treatment of these two metals has always been very similar, though the greater abundance of the latter metal has allowed it to be used on a larger scale and for a greater variety of purposes.

Bronze is an alloy of copper and tin in varying proportions, the proportion of tin being from 8 to 20 per cent. The great fluidity of bronze when melted, the slightness of its contraction on solidifying, together with its density and hardness, make it especially suitable for casting, and allow of its taking the impress of the mould with extreme sharpness and delicacy. In the form of plate it can be tempered and annealed till its elasticity and toughness are much increased, and it can then be formed into almost any shape under the hammer and punch. By other methods of treatment, known to the ancient Egyptians, Greeks, and others, but now forgotten, it could be hardened and formed into knife and razor edges of the utmost keenness. In many specimens of ancient bronze small quantities of silver, lead, and zinc have been found, but their presence is probably accidental.

In modern times, after the discovery of zinc, an alloy of copper and zinc called brass has been much used, chiefly for the sake of its cheapness as compared with bronze. In beauty, durability, and delicacy of surface it is very inferior to bronze, and, though of some commercial importance, has been of but little use in the production of works of art.

To some extent copper was used in an almost pure state during mediæval times, especially from the 12th to the 15th century, mainly for objects of ecclesiastical use, such as pyxes, monstrances, reliquaries, and croziers, partly on account of its softness under the tool, and also because it was slightly easier to apply enamel and gilding to pure copper than to bronze (see fig. 1). In the mediæval period it was used to some extent in the shape of thin sheeting for roofs, as at St Mark's, Venice; while during the 16th and 17th centuries it was largely employed for ornamental domestic vessels of various sorts.

Iron.[1]—The abundance in which iron is found in so many places, its great strength, its remarkable ductility and malleability in a red-hot state, and the ease with which two heated surfaces of iron can be welded together under the hammer combine to make it specially suitable for works on a large scale where strength with lightness are required—things such as screens, window-grills, ornamental hinges, and the like.

In its hot plastic state iron can be formed and modelled under the hammer to almost any degree of refinement, while its great strength allows it to be beaten out into leaves and ornaments of almost paper-like thinness and delicacy. With repeated hammering, drawing out, and annealing, it gains much in strength and toughness, and the addition of a very minute quantity of carbon converts

[1] Some recent analyses of the iron of prehistoric weapons have brought to light the interesting fact that many of these earliest specimens of iron manufacture contain a considerable percentage of nickel. This special alloy does not occur in any known iron ores, but is invariably found in meteoric iron. It thus appears that iron was manufactured from meteorolites which had fallen to the earth in an almost pure metallic state, possibly long before prehistoric man had learnt how to dig for and smelt iron in any of the forms of ore which are found on this planet.

it into steel, less tough, but of the keenest hardness. The large employment of cast iron is comparatively modern, in England at least only dating from the 16th century; it is not, however, incapable of artistic treatment if due regard be paid to the necessities of casting, and if no attempt is made to imitate the fine-drawn lightness to which wrought iron so readily lends itself. At the best, however, it is not generally suited for the finest work, as the great contraction of iron in passing from the fluid to the solid state renders the cast somewhat blunt and spiritless.

Among the Assyrians, Egyptians, and Greeks the use of iron, either cast or wrought, was very limited, bronze being the favourite metal for almost all purposes. The difficulty of smelting the ore was probably one reason for this, as well as the now forgotten skill which enabled bronze to be tempered to a steel-like edge. It had, however, its value, of which a proof occurs in Homer (*Il.* xxiii.), where a mass of iron is mentioned as being one of the prizes at the funeral games of Patroclus.

Methods of Manipulation in Metal-Work.—Gold, silver, and bronze may be treated in various ways, the chief of which are (1) casting in a mould, and (2) treatment by hammering and punching (French, *repoussé*).

The first of these, casting, is chiefly adapted for bronze, or in the case of the more precious metals only if they are used on a very small scale. The reason of this is that a repoussé relief is of much thinner substance than if the same design were cast, even by the most skilful metal-worker, and so a large surface may be produced with a very small expenditure of valuable metal.

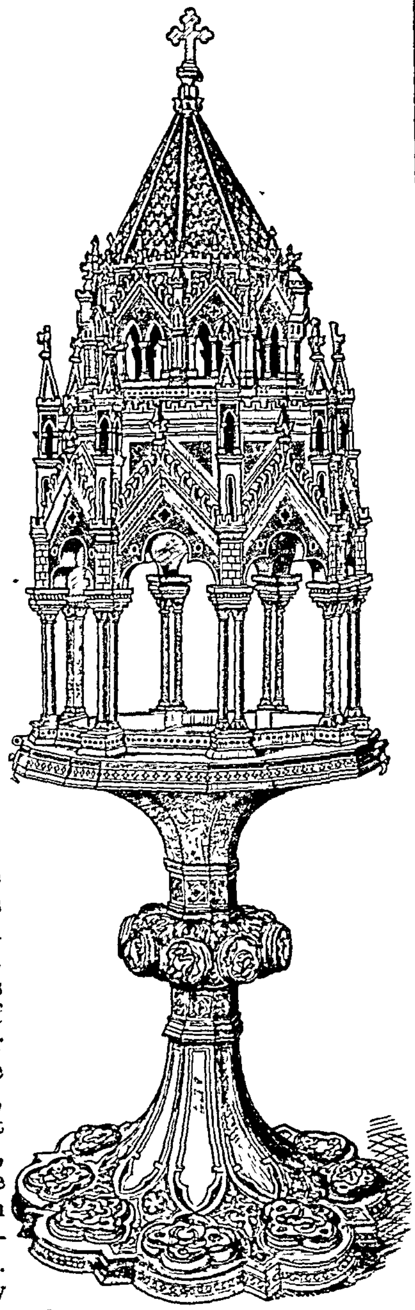


Fig. 1.—Monstrance of Copper Gilt; Italian work of the 15th century.

Casting is probably the most primitive method of metal-work. This has passed through three stages, the first being represented by solid castings, such as are most celts and other implements of the prehistoric time; the mould was formed of clay, sand, or stone, and the fluid metal was poured in till the hollow was full. The next stage was, in the case of bronze, to introduce an iron core, probably to save needless expenditure of the more valuable metal. The British Museum possesses an interesting Etruscan or Archaic Italian example of this primitive device. It is a bronze statuette from Sessa on the Volturno, about 2 feet high, of a female standing, robed in a close-fitting chiton. The presence of the iron core has been made visible by the splitting of the figure, owing to the unequal contraction of the two metals. The forearms, which are extended, have been cast separately and soldered or brazed on to the elbows.

The third and last stage in the progress of the art of casting was the employment of a core, generally of clay, round which the metal was cast in a mere skin, only thick enough for strength, without waste of metal. The Greeks and Romans attained to the greatest possible skill in this process. Their exact method is not certainly known, but it appears probable that they were acquainted with the process now called *à cire perdue*—the same as that employed by the great Italian artists in bronze, and still unimproved upon even at the present day. Cellini, the great Florentine artist of the 16th century, has described it fully in his *Trattato della Scultura.* If a statue was to be cast, the figure was first roughly modelled in clay—only rather smaller in all its dimensions than the future bronze; all over this a skin of wax was laid, and worked by the sculptor with modelling tools to the required form and finish. A mixture of pounded brick, clay, and ashes was then ground finely in water to the consistence of cream, and successive coats of this mixture were then applied with a brush, till a second skin was formed all over the wax, fitting closely into every line and depression of the modelling. Soft clay was then carefully laid on to strengthen the mould, in considerable thickness, till the whole statue appeared like a shapeless mass of clay, round which iron hoops were bound to hold it all together. The whole was then thoroughly dried, and placed in a hot oven, which baked the clay, both of the core and the outside mould, and melted the wax, which was allowed to run out from small holes made for the purpose. Thus a hollow was left, corresponding to the skin of wax between the core and the mould, the relative positions of which were preserved by various small rods of bronze, which had previously been driven through from the outer mould to the rough core. The mould was now ready, and melted bronze was poured in till the whole space between the core and the outer mould was full. After slowly cooling, the outer mould was broken away from outside the statue, and the inner core as much as possible broken up and raked out through a hole in the foot or some other part of the statue. The projecting rods of bronze were then cut away, and the whole finished by rubbing down and polishing over any roughnesses or defective places. The most skilful sculptors, however, had but little of this after-touching to do, the final modelling and even polish which they had put upon the wax being faithfully reproduced in the bronze casting.

The further enrichment of the object by enamels and inlay of other metals was practised at a very early period by Assyrian, Egyptian, and Greek metal-workers, as well as by the artists of Persia and mediæval Europe.

The second chief process, that of hammered work (Greek, *sphyrelata*; French, *repoussé*), was probably adopted for bronze-work on a large scale, before the art of forming large castings was discovered. In the most primitive method thin plates of bronze were hammered over a wooden core, rudely cut into the required shape, the core serving the double purpose of giving shape to and strengthening the thin metal.

A further development in the art of hammered work consisted in laying the metal plate on a soft and elastic bed of cement made of pitch and pounded brick. The design was then beaten into relief from the back with hammers and punches, the pitch bed yielding to the protuberances which were thus formed, and serving to pro-

vent the punch from breaking the metal into holes. The pitch was then melted away from the front of the embossed relief, and applied in a similar way to the back, so that the modelling could be completed on the face of the relief, the final touches being given by the graver. This process was chiefly applied by mediæval artists to the precious metals, but by the Assyrians, Greeks, and other early nations it was largely used for bronze.

The great gates of Shalmaneser II., 859–824 B.C., from Balawat, now in the British Museum, are a remarkable example of this sort of work on a large scale, though the treatment of the reliefs is minute and delicate. The "Siris bronzes," in the same museum, are a most astonishing example of the skill attained by Greek artists in this repoussé work (see Brönsted's *Bronzes of Siris*, 1836). They are a pair of shoulder-pieces from a suit of bronze armour, and each has in very high relief a combat between a Greek warrior and an Amazon. No work of art in metal has probably ever surpassed these little figures for beauty, vigour, and expression, while the skill with which the artist has beaten these high reliefs out of a flat plate of metal appears almost miraculous. The heads of the figures are nearly detached from the ground, their substance is little thicker than paper, and yet in no place has the metal been broken through by the punch. They are probably of the school of Praxiteles, and date from the 4th century B.C. (see fig. 2).

FIG. 2.—One of the Siris Bronzes.

Copper and tin have been but little used separately. Copper in its pure state may be worked by the same methods as bronze, but it is inferior to it in hardness, strength, and beauty of surface. Tin is too weak and brittle a metal to be employed alone for any but small objects. Some considerable number of tin drinking-cups and bowls of the Celtic period have been found in Cornwall in the neighbourhood of the celebrated tin and copper mines, which appear to have been worked from a very early period. The existence of these mines was known to the Phœnicians, who carried on a considerable trade in metals with the south-west corner of England and the Scilly Isles —probably the Cassiterides of Pliny and other classical writers.

The use of lead has been more extended. In sheets it forms the best of all coverings for roofs and even spires. In the Roman and mediæval periods it was largely used for coffins, which were often richly ornamented with cast work in relief. Though fusible at a very low temperature, and very soft, it has great power of resisting decay from damp or exposure. Its most important use in an artistic form has been in the shape of baptismal fonts, chiefly between the 11th and the 14th centuries. The superior beauty of colour and durability of old specimens of lead is owing to the natural presence of a small proportion of silver. Modern smelters carefully extract this silver from the lead ore, thereby greatly impairing the durability and beauty of the metal.

As in almost all the arts, the ancient Egyptians excelled in their metal-work, especially in the use of bronze and the precious metals. These were worked by casting and hammering, and ornamented by inlay, gilding, and enamels with the greatest possible skill.

From Egypt perhaps was derived the early skill of the Hebrews. Further instruction in the art of metal-working came probably to the Jews from the neighbouring country of Tyre. The description of the great gold lions of Solomon's throne, and the laver of cast bronze supported on figures of oxen, shows that the artificers of that time had overcome the difficulties of metal-working and founding on a large scale. The Assyrians were perhaps the most remarkable of all ancient nations for the colossal size and splendour of their works in metal; whole circuit walls of great cities, such as Ecbatana, are said to have been covered with metal plates, gilt or silvered.

Herodotus, Athenæus, and other Greek and Roman writers have recorded the enormous number of colossal statues and other works of art for which Babylon and Nineveh were so famed. The numerous objects of bronze and other metals brought to light by the excavations of the last forty years in the Tigris and Euphrates valleys, though mostly on a small scale, bear witness to the great skill and artistic power of the people who produced them; while the recent discovery of some bronze statuettes, shown by inscriptions on them to be not later than 2200 B.C., proves how early was the development of this branch of art among the people of Assyria.

The Metal-Work of Greece.—The poems of Homer are full of descriptions of elaborate works in bronze, iron, gold, and silver, which, even when full allowance is made for poetic fancy, show clearly enough a very advanced amount of skill in the working and ornamenting of these metals among the Greeks of his time. His description of the shield of Achilles, made of bronze, enriched with bands of figure reliefs in gold, silver, and tin, could hardly have been written by a man who had not some personal acquaintance with works in metal of a very elaborate kind. Again, the accuracy of his descriptions of brazen houses—such as that of Alcinous, *Od.* vii. 81—is borne witness to by Pausanias's mention of the bronze temple of Athena Χαλκίοικος in Sparta, and the bronze chamber dedicated to Myron in 648 B.C., as well as by the discovery of the stains and bronze nails, which show that the whole interior of the so-called treasury of Atreus at Mycenæ was once

covered with a lining of bronze plates. Of the two chief methods of working bronze, gold, and silver, it is probable that the hammer process was first practised, at least for statues, among the Greeks, who themselves attributed the invention of the art of hollow casting to Theodorus and Rhœcus, both Samian sculptors, about the middle of the 6th century B.C. Pausanias specially mentions that one of the oldest statues he had ever seen was a large figure of Zeus in Sparta, made of hammered bronze plates riveted together. With increased skill in large castings, and the discovery of the use of cores, by which the fluid bronze was poured into a mere skin-like cavity, hammered or repoussé work (Greek, *sphyrelata*) was only used for small objects where lightness was desirable, or for the precious metals in order to avoid large expenditure of metal. The colossal statues of ivory and gold by Phidias were the most notable examples of this use of gold, especially his statue of Athena in the Parthenon, and the one of Zeus at Olympia. The nude parts, such as face and hands, were of ivory, while the armour and drapery were of beaten gold. The comparatively small weight of gold used by Phidias is very remarkable when the great size of the statues is considered.

A graphic representation of the workshop of a Greek sculptor in bronze is given on a fictile vase now in the Berlin Museum (see Gerhard's *Trinkschalen*, plates xii., xiii.). One man is raking out the fire in a high furnace, while another behind is blowing the bellows. Two others are smoothing the surface of a statue with scraping tools, formed like a strigil. A fourth is beating the arm of an unfinished figure, the head of which lies at the workman's feet. Perhaps the most important of early Greek works in cast bronze, both from its size and great historical interest, is the bronze pillar (now in the Hippodrome at Constantinople) which was erected to commemorate the victory of the allied Greek states over the Persians at Platæa in 479 B.C. (see Newton's *Travels in the Levant*). It is in the form of three serpents twisted together, and before the heads were broken off was at least 20 feet high. It is cast hollow, all in one piece, and has the names of the allied states engraved on the lower part of the coils. Its size and the beauty of its surface show great technical skill in the founder's art. On it once stood the gold tripod dedicated to Apollo as a tenth of the spoils. It is described both by Herodotus and Pausanias.

Marble was comparatively but little used by the earlier Greek sculptors, and even Myron, a rather older man than Phidias, seems to have executed nearly all his most important statues in metal.

Additional richness was given to Greek bronze-work by gold or silver inlay on lips, eyes, and borders of the dress; one remarkable statuette in the British Museum has eyes inlaid with diamonds, and fret-work inlay in silver on the border of the chiton.

The mirrors of the Greeks are among the most important specimens of their artistic metal-work. These are bronze disks, one side polished to serve as a reflector, and the back ornamented with engraved outline drawings, often of great beauty (see Gerhard, *Etruskische Spiegel*, 1843–67).

The Greek workman, in fact, was incapable of making an ugly thing. Whatever the metal or whatever the object formed, whether armour, personal ornaments, or domestic vessels, the form was always specially adapted to its use, the ornament natural and graceful, so that the commonest water-jar was a delight alike to him who made it and those who used it.

In metal-work, as in other arts, the Romans were pupils and imitators of the Greeks. Owing to the growth of that spirit of luxury which in time caused the extinction of the Roman empire, a considerable demand arose for magnificent articles of gold and silver plate. The finest specimens of these that still exist are the very beautiful set of silver plate found buried near Hildesheim in 1869, now in the Berlin Museum. They consist of drinking vessels, bowls, vases, ladles, and other objects of silver, parcel-gilt, and exquisitely decorated with figures in relief, both cast and repoussé. There are electrotypes of these in the South Kensington Museum.

When the seat of the empire was changed from Rome to Byzantium, the latter city became the chief centre for the production of artistic metal-work. From Byzantium the special skill in this art was transmitted in the 9th and 10th centuries to the Rhenish provinces of Germany and to Italy, and thence to the whole of Western Europe; in this way the 18th-century smith who wrought the Hampton Court iron gates was the heir to the mechanical skill of the ancient metal-workers of Phœnicia and Greece.

In that period of extreme degradation into which all the higher arts fell after the destruction of the Roman empire, though true feeling for beauty and knowledge of the subtleties of the human form remained for centuries almost dormant, yet at Byzantium at least there still survived great technical skill and power in the production of all sorts of metal-work. In the age of Justinian (first half of the 6th century) the great church of St Sophia at Constantinople was adorned with an almost incredible amount of wealth and splendour in the form of screens, altars, candlesticks, and other ecclesiastical furniture made of massive gold and silver.

Metal-Work in Italy.—It was therefore to Byzantium that Italy turned for metal-workers, and especially for goldsmiths, when, in the 6th to the 8th centuries, the basilica of St Peter's in Rome was enriched with masses of gold and silver for decorations and fittings, the gifts of many donors from Belisarius to Leo III., the mere catalogue of which reads like a tale from the *Arabian Nights.* The gorgeous Pala d'Oro, still in St Mark's at Venice, a gold retable covered with delicate reliefs and enriched with enamels and jewels, was the work of Byzantine artists during the 11th century. This work was in progress for more than a hundred years, and was set in its place in 1106 A.D., though still unfinished (see Bellomo, *Pala d'Oro di S. Marco*, 1847).

It was, however, especially for the production of bronze doors for churches, ornamented with panels of cast work in high relief, that Italy obtained the services of Byzantine workmen (see Garrucci, *Arte Cristiana*, 1872–82). One artist named Staurachios produced many works of this class, some of which still exist, such as the bronze doors of the cathedral at Amalfi, dated 1066 A.D. Probably by the same artist, though his name was spelled differently, were the bronze doors of San Paolo fuori le Mura, Rome, careful drawings of which exist, though the originals were destroyed in the fire of 1824. Other important examples exist at Ravello (1197), Salerno (1099), Amalfi (1062), Atrani (1087); and doors at Monreale in Sicily and at Trani, signed by an artist named Barisanos (end of the 12th century); the reliefs on these last are remarkable for expression and dignity, in spite of their early rudeness of modelling and ignorance of the human figure.

Most of these works in bronze were enriched with fine lines inlaid in silver, and in some cases with a kind of niello or enamel. The technical skill of these Byzantine metal-workers was soon acquired by native Italian artists, who produced many important works in bronze similar in style and execution to those of the Byzantine Greeks. Such, for example, are the bronze doors of San Zenone at Verona (unlike the others, of repoussé not cast work); those of the Duomo of Pisa, cast in 1180 by Bonannus, and of the

Duomo of Troia, the last made in the beginning of the 12th century by Oderisius of Benevento. Another artist named Roger of Amalfi worked in the same way; and in the year 1219 the brothers Hubertus and Petrus of Piacenza cast the bronze door for one of the side chapels in San Giovanni in Laterano. One of the most important early specimens of metal-work is the gold and silver altar of Sant' Ambrogio in Milan. In character of work and design it resembles the Venice Pala d'Oro, but is still earlier in date, being a gift to the church from Archbishop Angilbert II. in 835 A.D. (see Du Sommerard, and D'Agincourt, *Moyen Âge*). It is signed WOLVINIVS MAGISTER PHABER; nothing is known of the artist, but he probably belonged to the semi-Byzantine school of the Rhine provinces; according to Dr Rock he was an Anglo-Saxon goldsmith. It is a very sumptuous work, the front of the altar being entirely of gold, with repoussé reliefs and cloisonnée enamels; the back and ends are of silver, with gold ornaments. On the front are figures of Christ and the twelves apostles; the ends and back have reliefs illustrating the life of St Ambrose.

The most important existing work of art in metal of the 13th century is the great candelabrum now in Milan cathedral. It is of gilt bronze, more than 14 feet high; it has seven branches for candles, and its upright stem is supported on four winged dragons. For delicate and spirited execution, together with refined gracefulness of design, it is unsurpassed by any similar work of art. Every one of the numerous little figures with which it is adorned is worthy of study for the beauty and expression of the face, and the dignified arrangement of the drapery (see fig. 3).

FIG. 3.—Boss from the Milanese Candelabrum.

The semi-conventional open scroll-work of branches and fruit which wind around and frame each figure or group is devised with the most perfect taste and richness of fancy, while each minute part of this great piece of metal-work is finished with all the care that could have been bestowed on the smallest article of gold jewellery. Though something in the grotesque dragons of the base recalls the Byzantine school, yet the beauty of the figures and the keen feeling for graceful curves and folds in the drapery point to a native Italian as being the artist who produced this wonderful work of art. There is a cast in the South Kensington Museum.

During the 13th and 14th centuries in Italy the wide-spread influence of Niccolo Pisano and his school encouraged the sculptor to use marble rather than bronze for his work. At this period wrought iron came into general use in the form of screens for chapels and tombs, and grills for windows. These are mostly of great beauty, and show remarkable skill in the use of the hammer, as well as power in adapting the design to the requirements of the material. Among the finest examples of this sort of work are the screens round the tombs of the Scala family at Verona, 1350–75,—a sort of net-work of light cusped quatrefoils, each filled up with a small ladder (scala) in allusion to the name of the family. The most elaborate specimen of this wrought work is the screen to the Rinuccini chapel in Santa Croce, Florence, of 1371, in which moulded pillars and window-like tracery have been wrought and modelled by the hammer with extraordinary skill (see Wyatt, *Metal-Work of Middle Ages*). Of about the same date are the almost equally magnificent screens in Sta Trinita, Florence, and at Siena across the chapel in the Palazzo Pubblico. The main part of most of these screens is filled in with quatre-foils, and at the top is an open frieze formed of plate iron pierced, repoussé, and enriched with engraving.

In the 14th century great quantities of objects for ecclesiastical use were produced in Italy, some on a large scale, and mostly the works of the best artists of the time.

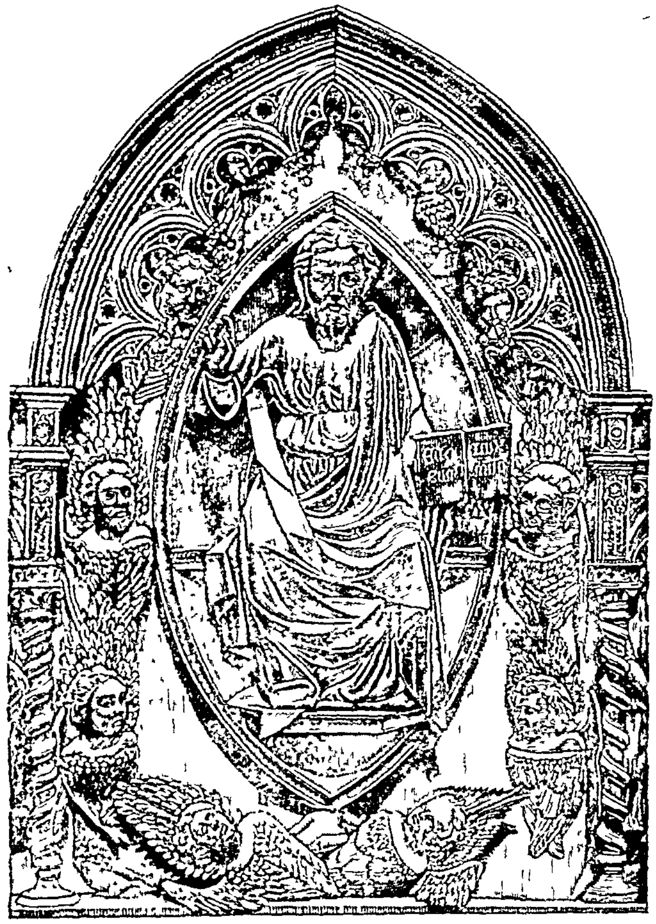


FIG. 4.—Silver Repoussé Reliefs from the Pistoia Retable.

The silver altar of the Florence baptistery is one of the chief of these; it was begun in the first half of the 14th century, and not completed till after 1477 (see *Gaz. des Beaux Arts*, Jan. 1883). A whole series of the greatest artists in metal laboured on it in succession, among whom were Orcagna, Ghiberti, Verrocchio, Ant. Pollajuolo, and many others. It has elaborate reliefs in repoussé work, cast canopies, and minute statuettes, with the further enrichment of translucent coloured enamels. The silver altar and retable of Pistoia cathedral (see fig. 4), and the great shrine at Orvieto, are works of the same class, and of equal importance.

Whole volumes might be devoted to the magnificent works in bronze produced by the Florentine artists of this century, works such as the baptistery gates by Ghiberti, and the statues of Verrocchio, Donatello, and many others, but these come rather under the head of sculpture.

Some very magnificent bronze screens were produced at this time, especially that in Prato cathedral by Simone, brother of Donatello, in 1444–61, and the screen and bronze ornaments of the tomb of Piero and Giovanni dei Medici in San Lorenzo, Florence, by Verrocchio, in 1472.

At the latter part of the 15th century and the beginning of the 16th the Pollajuoli, Ricci, and other artists devoted much labour and artistic skill to the production of candlesticks and smaller objects of bronze, such as door-knockers, many of which are works of the greatest beauty. The candlesticks in the Certosa near Pavia, and in the cathedrals of Venice and Padua, are the finest examples of these.

Niccolò Grossi, who worked in wrought iron under the patronage of Lorenzo dei Medici, produced some wonderful specimens of metal-work, such as the candlesticks, lanterns, and rings fixed at intervals round the outside of the great palaces (see fig. 5). The Strozzi palace in Florence and the Palazzo del Magnifico at Siena have fine specimens of these,—the former of wrought iron, the latter in cast bronze.

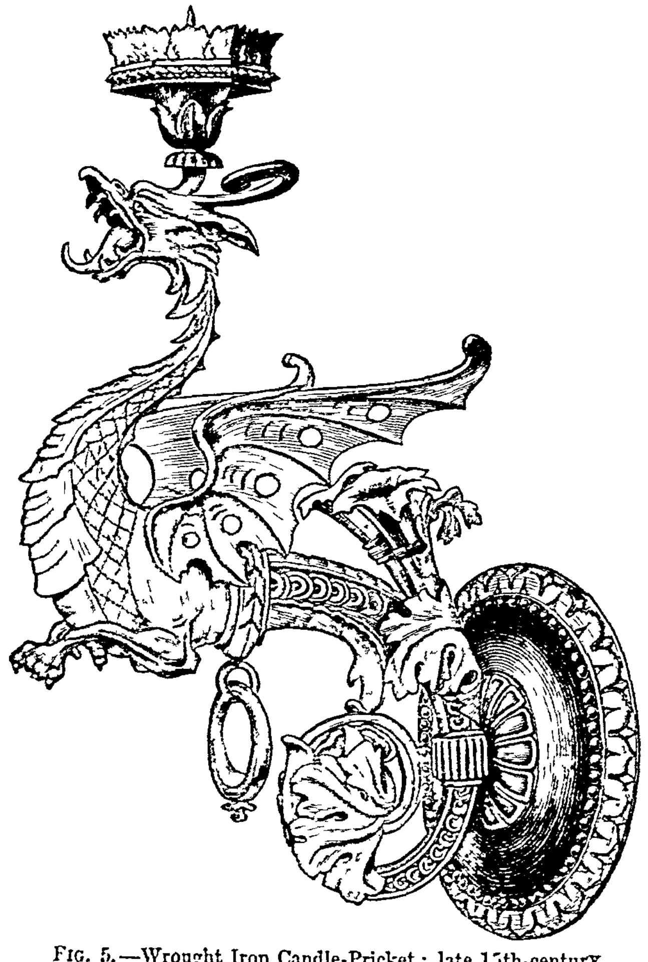


Fig. 5.—Wrought Iron Candle-Pricket; late 15th-century. Florentine work.

At Venice fine work in metal, such as salvers and vases, was being produced, of almost Oriental design, and in some cases the work of resident Arab artificers. In the 16th century Benvenuto Cellini was supreme for skill in the production of enamelled jewellery, plate, and even larger works of sculpture (see Plon's *Ben. Cellini*, 1882), and John of Bologna in the latter part of the same century inherited to some extent the skill and artistic power of the great 15th-century artists. Since that time Italy, like other countries, has produced little metal-work of real value.

Spain.—From a very early period the metal-workers of Spain have been distinguished for their skill, especially in the use of the precious metals. A very remarkable set of specimens of goldsmith's work of the 7th century are the eleven votive crowns, two crosses, and other objects found in 1858 at Guarrazar, and now preserved at Madrid and in Paris in the Cluny Museum (see Du Sommerard, *Musée de Cluny*, 1852). Magnificent works in silver, such as shrines, altar crosses, and church vessels of all kinds, were produced in Spain from the 14th to the 16th century,—especially a number of sumptuous tabernacles (*custodia*) for the host, magnificent examples of which still exist in the cathedrals of Toledo and Seville. The bronze and wrought iron screens—*rejas*, mostly of the 15th and 16th centuries—to be found in almost every important church in Spain are very fine examples of metal-work. They generally have moulded rails or ballusters, and rich friezes of pierced and repoussé work, the whole being often thickly plated with silver. The common use of metal for pulpits is a peculiarity of Spain; they are sometimes of bronze, as the pairs in Burgos and Toledo cathedrals, or in wrought iron, like those at Zamora and in the church of San Gil, Burgos. The great candelabrum or *tenebrarium* in Seville cathedral is the finest specimen of 16th-century metal-work in Spain; it was mainly the work of Bart. Morel in 1562. It is of cast bronze enriched with delicate scroll-work foliage, and with numbers of well-modelled statuettes, the general effect being very rich and graceful. Especially in the art of metal-work Spain was much influenced in the 15th and 16th centuries by both Italy and Germany, so that numberless Spanish objects produced at that time owe little or nothing to native designers. At an earlier period Arab and Moorish influence is no less apparent.

England.—In Saxon times the English metal-workers, especially of the precious metals, possessed great skill, and appear to have produced shrines, altar-frontals, retables, and other ecclesiastical furniture of considerable size and magnificence.

Dunstan, archbishop of Canterbury (925–988), like Bernward, bishop of Hildesheim a few years later, and St Eloi of France three centuries earlier, was himself a skilful worker in all kinds of metal. The description of the gold and silver retable given to the high altar of Ely by Abbot Theodwin in the 11th century, shows it to have been a large and elaborate piece of work decorated with many reliefs and figures in the round. In 1241 Henry III. gave the order for the great gold shrine to contain the bones of Edward the Confessor (see W. Burges in *Gleanings from Westminster*). It was the work of members of the Otho family, among whom the goldsmith's and coiner's crafts appear to have been long hereditary. Countless other important works in the precious metals adorned every abbey and cathedral church in the kingdom.

In the 13th century the English workers in wrought iron were especially skilful. The grill over the tomb of Queen Eleanor at Westminster, by Thomas de Leghton, made about 1294, is a remarkable example of skill in welding and modelling with the hammer (see fig. 6).

The rich and graceful iron hinges, made often for small and out-of-the-way country churches, are a large and important class in the list of English wrought iron-work. Those on the refectory door of Merton College, Oxford, are a beautiful and well-preserved example dating from the 14th century.

More mechanical in execution, though still very rich in effect, is that sort of iron tracery work produced by cutting out patterns in plate, and superimposing one plate over the other, so as to give richness of effect by the shadows produced by these varying planes. The screen by Henry V.'s tomb at Westminster is a good early specimen of this kind of work.

The screen to Bishop West's chapel at Ely, and that round Edward IV.'s tomb at Windsor, both made towards the end of the 15th century, are the most magnificent

English examples of wrought iron, in which every art and feat of skill known to the smith has been brought into play to give variety and richness to the work.

Much wrought-iron work of great beauty was produced at the beginning of the 18th century, especially under the superintendence of Sir Christopher Wren (see Ebbetts, *Iron Work of 17th and 18th Centuries*, 1880). Large flowing leaves of acanthus and other plants were beaten out with wonderful spirit and beauty of curve. The gates from Hampton Court are the finest examples of this class of work (see fig. 7).

From an early period bronze and latten (a variety of brass) were much used in England for the smaller objects both of ecclesiastical and domestic use, but except for tombs and lecterns were but little used on a large scale till the 16th century. The full-length recumbent effigies of Henry III. and Queen Eleanor at Westminster, cast in bronze by the "cire perdue" process, and thickly gilt, are equal, if not superior, in artistic beauty to any sculptor's work of the same period (end of the 13th century) that was produced in Italy or elsewhere. These effigies are the work

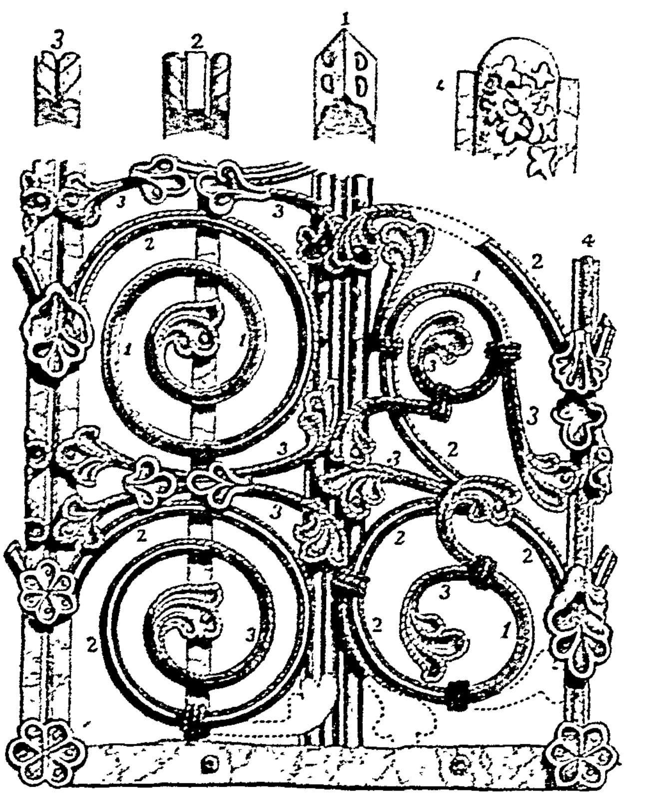


Fig. 6.—Part of the "Eleanor Grill."

of an Englishman named William Torel (see *Westminster Gleanings*). The gates to Henry VII.'s chapel, and the screen round his tomb at Westminster (see fig. 8), are very elaborate and beautiful examples of "latten" work, showing the greatest technical skill in the founder's art. In latten also were produced the numerous monumental brasses of which about two thousand still exist in England. Though a few were made in the 13th century, yet it was not till the 14th that they came into general use. They are made of cast plates of brass, with the design worked upon them with the chisel and graver. All those, however, to be seen in English churches are not of native work—great quantities of them being Flemish imports (see Cotman, Waller, and Boutell on Monumental Brasses).

In addition to its chief use as a roof covering, lead was sometimes used in England for making fonts, generally tub-shaped, with figures cast in relief. Many examples exist: *e.g.*, at Tidenham, Gloucestershire; Warborough and Dorchester, Oxon; Chirton, Wilts; and other places.

Germany.—Unlike England, Germany in the 10th and 11th centuries produced large and elaborate works in cast bronze, especially doors for churches, much resembling the contemporary doors made in Italy under Byzantine influence. Bernward, bishop of Hildesheim, 992–1022, was especially skilled in this work, and was much influenced in design by a visit to Rome in the suite of Otho III. The bronze column with winding reliefs now at Hildesheim was the result of his study of Trajan's column, and the bronze door which he made for his own cathedral shows classical influence, especially in the composition of the drapery of the figures in the panels.

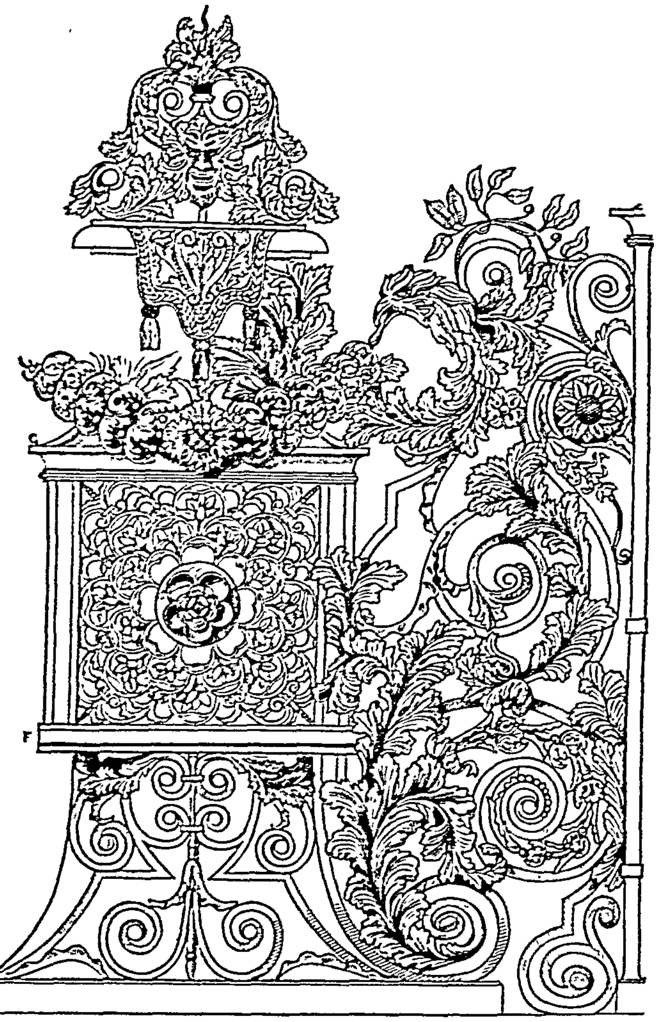


Fig. 7.—Part of one of the Hampton Court Gates.

The bronze doors of Augsburg (1047–72) are similar in style. The bronze tomb of Rudolph of Swabia in Mersburg cathedral (1080) is another fine work of the same school. The production of works in gold and silver was also carried on vigorously in Germany. The shrine of the three kings at Cologne is the finest surviving example.

At a later time Augsburg and Nuremberg were the chief centres for the production of artistic works in the various metals. Herman Vischer, in the 15th century, and his son and grandsons were very remarkable as bronze founders. The font at Wittenberg, decorated with reliefs of the apostles, was the work of the elder Vischer, while Peter and his son produced, among other important works, the shrine of St Sebald at Nuremberg, a work of great finish and of astonishing richness of fancy in its design (see Doebner, *Christliches Kunstblatt*, 1866, Nos. 10–12). The tomb of Maximilian I., and the statues round it, at Innsbruck, begun in 1521, are perhaps the most meritorious German work of this class in the 16th century, and show considerable Italian influence.

In wrought iron the German smiths, especially during the 15th century, greatly excelled. Almost peculiar to Germany is the use of wrought iron for grave-crosses and sepulchral monuments, of which the Nuremberg and other cemeteries contain fine examples. Many elaborate well-canopies were made in wrought iron, and gave full play to the fancy and invention of the smith. The celebrated 15th-century example over the well at Antwerp, attributed to Quintin Massys, is the finest of these.

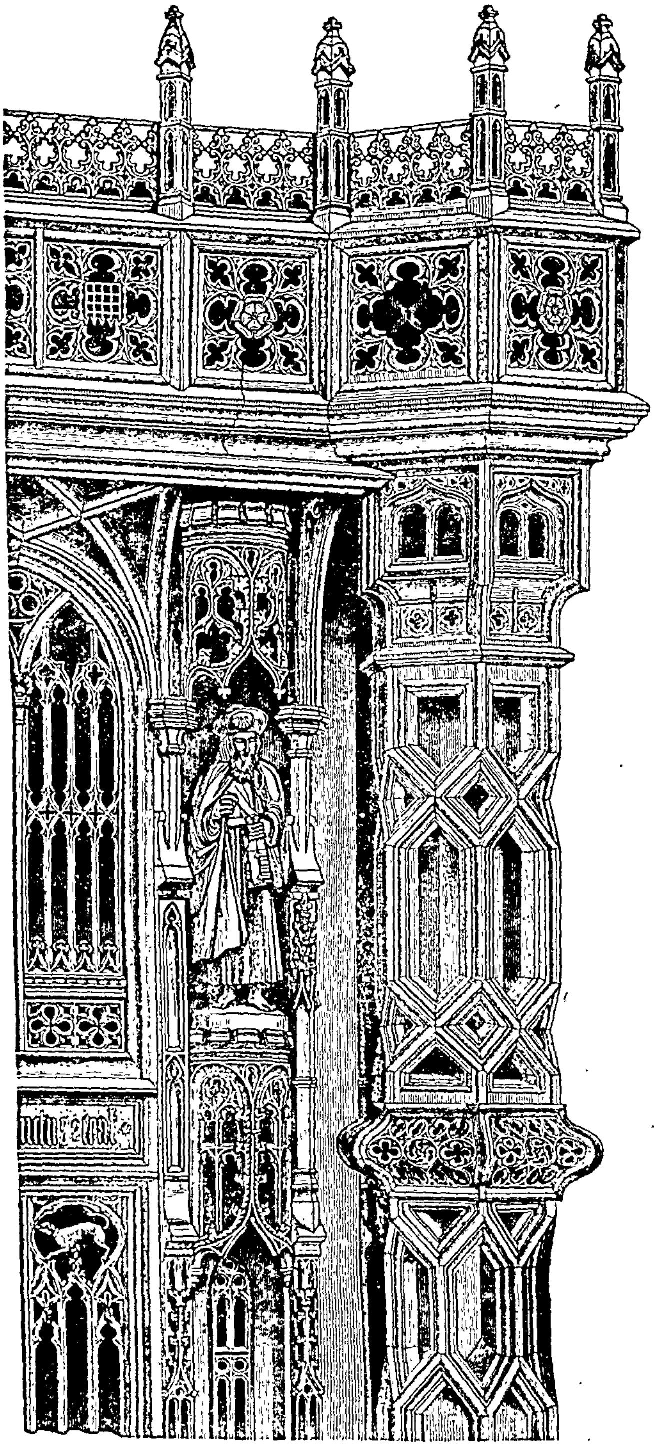


FIG. 8.—Part of Henry VII.'s Bronze Screen.

France.—From the time of the Romans the city of Limoges has been celebrated for all sorts of metal-work, and especially for brass enriched with enamel. In the 13th and 14th centuries many life-size sepulchral effigies were made of beaten copper or bronze, and ornamented by various-coloured "champlevé" enamels. The beauty of these effigies led to their being imported into England; most are now destroyed, but a fine specimen still exists at Westminster on the tomb of William de Valence (1296). In ornamental iron-work for doors the French smiths were pre-eminent for the richness of design and skilful treatment of their metal. No examples probably surpass those on the west doors of Notre Dame in Paris—now unhappily much falsified by restoration. The crockets and finials on the flèches of Amiens and Rheims are beautiful specimens of a highly ornamental treatment of cast lead, for which France was especially celebrated. In most respects, however, the development of the various kinds of metal-working went through much the same stages as in England.

Persia and Damascus.—The metal-workers of the East, especially in brass and steel, were renowned for their skill even in the time of Theophilus, the monkish writer on the subject in the 13th century. But it was during the reign of Shah Abbas I. (d. 1628) that the greatest amount of skill both in design and execution was reached by the Persian workmen. Delicate pierced vessels of gilt brass, enriched by tooling and inlay of gold and silver, were among the chief specialties of the Persians (see fig. 9).

FIG. 9.—Brass Vase, pierced and gilt; 17th century Persian work.

A process called by Europeans "damascening" (from Damascus, the chief seat of the export) was used to produce very delicate and rich surface ornament. A pattern was incised with a graver in iron or steel, and then gold wire was beaten into the sunk lines, the whole surface being then smoothed and polished. In the time of Cellini this process was copied in Italy, and largely used, especially for the decoration of weapons and armour. The repoussé process both for brass and silver was much used by Oriental workers, and even now fine works of this class are produced in the East, old designs still being adhered to.

Recent Metal-Work.—In modern Europe generally the arts of metal-working both as regards design and technical skill are not in a flourishing condition. The great bronze lions of the Nelson monument in London are a sad example of the present low state of the founder's art. Coarse sand-casting in England now takes the place of the delicate "cire perdue" process.

Some attempts have lately been made in Germany to revive the art of good wrought-iron work. The Prussian gates, bought at a high price for the South Kensington Museum, are large and pretentious, but unfortunately are only of value as a warning to show what wrought iron ought not to be. Some English recent specimens of hammered work are more hopeful, and show that one or two smiths are working in the right direction.

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METAMORPHOSIS. This term has been employed in several distinct senses in biology. During the early part of the century it was constantly used to include the current morphological conceptions, as, for instance, of the parts of a flower as modified or "metamorphosed" leaves, or of the segments of a skull as modified vertebræ. It is still frequently employed to denote that progressive change from the general to the special undergone by all developing tissues and organs (see BIOLOGY, EMBRYOLOGY), but in this sense is conveniently superseded by the term "differentiation." In the process of animal development, two types are broadly distinguishable,—a fœtal type, in which development takes place wholly or in greater part either within the egg or within the body of the parent, and a larval type, in which the young are born in a condition more or less differing from that of the adult, while the adult stage again is reached in one of two ways, either by a process of gradual change, or by a succession of more or less rapid and striking transformations, to which the term metamorphosis is now usually restricted. Metamorphosis is generally regarded as having been brought about by the action of natural selection, partly in curtailing and reducing the phases of development (an obvious advantage in economy of both structural and functional change), and partly also in favouring the acquirement of such secondary characters as are advantageous in the struggle for existence. Freshwater and terrestrial animals develop without metamorphosis much more frequently than marine members of the same group, a circumstance which has been variously explained. For details of metamorphoses see the articles on the various groups of animals; see also Balfour's *Comparative Embryology*, 1880–81.

METAPHYSIC

THE term metaphysic, originally intended to mark the place of a particular treatise in the collection of Aristotle's works, has, mainly owing to a misunderstanding, survived several other titles,—such as "First Philosophy," "Ontology," and "Theology," which Aristotle himself used or suggested. Neo-Platonic mystics interpreted it as signifying that which is not merely "after" but "beyond" physics, and found in it a fit designation for a science which, as they held, could not be attained except by one who had turned his back upon the natural world. And writers of a different tendency in a later time gladly accepted it as a convenient nickname for theories which they regarded as having no basis in experience, in the same spirit in which the great German minister Stein used the analogous title of "metapolitics" for airy and unpractical schemes of social reform. A brief indication of the contents of Aristotle's treatise may enable us to give a general definition of the science which was first distinctly constituted by it, and to determine in what sense the subjects which that science has to consider are beyond nature and experience.

For Aristotle, metaphysic is the science which has to do with Being as such, Being in general, as distinguished from the special sciences which deal with special forms of being. There are certain questions which, in Aristotle's view, we have a right to ask in regard to everything that presents itself as real. We may ask what is its ideal nature or definition, and what are the conditions of its realization; we may ask by what or whom it was produced, and for what end; we may ask, in other words, for the formal and the material, for the efficient and the final causes of everything that is. These different questions point to different elements in our notion of Being, elements which may be considered in their general relations apart from any particular case of their union. These, therefore, the first philosophy must investigate. But, further, this science of being cannot be entirely separated from the science of knowing, but must determine at least its most general principles. For the science that deals with what is most universal in being is, for that very reason, dealing with the objects which are most nearly akin to the intelligence. These, indeed, are not the objects which are first presented to our minds; we begin with the particular, not the universal, with a πρῶτον ἡμῖν which is not πρῶτον φύσει; but science reaches its true form only when the order of thought is made one with the order of nature, and the particular is known through the universal. Yet this conversion or revolution of the intellectual point of view is not to be regarded as an absolute change from error to truth; for Aristotle holds that *nihil est in intellectu quod non prius in sensu*, in the meaning that in sense perception there is already the working of that discriminative intelli-

gence[1] which, beginning in sense perception, with the distinction of particular from particular, can rest only when it has apprehended things in their universal forms or definitions. Looking at knowledge *formally*, the highest law of thought, the law of contradiction (or, as we might call it, to indicate Aristotle's meaning more exactly, the law of definition or distinction), is already implied in the first act of perception by which one thing is distinguished from another. Looking at it *materially*, the reason of man is to be conceived as potentially all that is knowable; *i.e.*, objects are so related to it that for it to know them in their essential definitions is only to know itself. The aim of science, in this view, is to break through the husk of matter, and to apprehend things in their forms, in which they are one with the mind that knows them. Hence also it follows that in rising to the most universal science, the science of Being in general, the mind is not leaving the region of immediate experience, in which it is at home, for a far-off region of abstractions. Rather it is returning to itself, apprehending that which is most closely related to itself, and which therefore, though it is late in being made the direct object of investigation, is yet presupposed in all that is, and is known.[2]

Metaphysic, then, is the science which deals with the principles which are presupposed in all being and knowing, though they are brought to light only by philosophy. Another trait completes the Aristotelian account of it. It is theology, or the science of God. Now God is νόησις νοήσεως, pure self-consciousness, the absolute thought which is one with its object, and He is therefore the first cause of all existence. For, while the world of nature is a world of motion and change, in which form is realized in matter, this process of the finite can be explained only by referring it back to an unmoved mover, in whom there is no distinction of matter and form, and who is, therefore, in Aristotle's view, to be conceived as pure form, the purely ideal or theoretic activity of a consciousness whose object is itself. Such a conception, however, while it secures the independence and absoluteness of the unmoved mover, by removing him from all relation to what is other than himself, seems to make his connexion with the world inexplicable. We can on this theory refer the world to God, but not God to the world. Hence Aristotle seems sometimes to say that God is the first mover only as He is the last end after which all creation strives, and this leads him to attribute to nature a desire or will which is directed towards the good as its object or end.

Aristotle then brings together in his metaphysic three elements which are often separated from each other, and the connexion of which is far from being at once obvious. It is to him the science of the first principles of being. It is also the science of the first principles of knowing. Lastly, it is the science of God, as the beginning and end of all things, the absolute unity of being and thought, in which all the differences of finite thought and existence are either excluded or overcome.

To some this description of the contents of Aristotle's treatise, and especially the last part of it, may seem to be a confirmation of all the worst charges brought against metaphysic. For at both extremes this supposed science seems to deal with that which is beyond experience, and which therefore cannot be verified by it. It takes us back to a beginning which is prior to the existence as well as to the consciousness of finite objects in time and space, and on to an end to which no scientific prophecy based upon our consciousness of such objects can reach. In the former aspect of it, it has to do with notions so abstract and general that it seems as if they could not be fixed or tested by reference to any experience, but must necessarily be the playthings of dialectical sophistry. In the latter aspect of it, it entangles us in questions as to the final cause and ultimate meaning of things, questions involving so comprehensive a view of the infinite universe in which we are insignificant parts that it seems as if any attempt to answer them must be for us vain and presumptuous. On both sides, therefore, metaphysic appears to be an attempt to occupy regions which are beyond the habitable space of the intelligible world—to deal with ideas which are either so vague and abstract that they cannot be fastened to any definite meaning, or so complex and far-reaching that they can never by any possibility be verified. For beings like men, fixed within these narrow limits of space and time, the true course, it would seem, is to "cultivate their gardens," asking neither whence they come nor whither they go, or asking it only within the possible limits of history and scientific prophecy. To go back to the beginning or on to the end is beyond them, even in a temporal, still more in a metaphysical, sense. That which is πρῶτον φύσει escapes us even more absolutely than the prehistorical and pregeological records of man and his world. That which is ὕστατον φύσει escapes us even more absolutely than the far-off future type of civilization, which social science vainly endeavours to anticipate. Our state is best pictured by that early Anglican philosopher who compared it to a bird flying through a lighted room "between the night and the night." The true aim of philosophy is, therefore, it would seem, to direct our thoughts to the careful examination and utilization of the narrow space allotted to us by an inscrutable power, and with scientific self-restraint to refrain from all speculation either on first or on final causes.

The main questions as to the possibility and the nature of metaphysic, according to Aristotle's conception of it, may be summed up under two heads. We may ask whether we can in any sense reach that which is beyond experience, and, if so, whether this "beyond" is a first or a last principle, a pre-condition or a final cause of nature and experience, or both. The former question branches out into two, according as we look at metaphysic from the objective or the subjective side, or, to express the matter more accurately, according as we consider it in relation to those natural objects which are *merely* objects of knowledge, or in relation to those spiritual objects which are also subjects of knowledge. We shall therefore consider metaphysic, first, in relation to science in general, and, secondly, in relation to the special science of psychology. The latter question also has two aspects; for, while the idea of a first cause or principle points to the connexion between metaphysic and logic, the idea of a last principle or final cause connects metaphysic with theology. We shall therefore consider in the third place the relation of metaphysic to logic, and in the fourth place its relation to religion and the philosophy of religion.

1. *The Relation of Metaphysic to Science.*—The beginnings of science and metaphysic are identical, though there is a sense in which it may be admitted that the metaphysical comes before the scientific or positive era. The first efforts of philosophy grasp at once at the prize of absolute knowledge. No sooner did the Greeks become dissatisfied with the pictorial synthesis of mythology by which their thoughts were first lifted above the confusion of particular things, than they asked for one universal principle which should explain all things. The Ionic school sought to find some one phenomenon of nature which might be used as the key to all other phenomena. The Eleatics, seeing the

[1] Δύναμις κριτική, *Anal. Post.*, ii. 99*b*.

[2] What is said here as to the intelligence is partly taken from the *De Anima*. The necessary qualifications of the above general statement of Aristotle's views will be given subsequently.

futility of making one finite thing the explanation of all other finite things, tried to find that explanation in the very notion of unity or being itself. We need not underestimate the speculative value of such bold attempts to sum up all the variety of the world in one idea, but it is obvious that they rather give a name to the problem than solve it, or that they put the very consciousness of the problem in place of the solution of it. Science is possible only if we can rise from the particular to the universal, from a subjective view of things as they immediately present themselves to us in perception to an objective determination of them through laws and principles which have no special relation to any particular set of events or to any one individual subject. But this is only one aspect of the matter. To advance from a conception of the world *in ordine ad individuum* to one *in ordine ad universum*, and so to discount and eliminate what is merely subjective and accidental in our first consciousness of the world, is the beginning of knowledge. But little is gained unless the universal, which we reach through the negation of the particulars, is more than their mere negation; unless it is a law or principle by means of which we can explain the particulars. Now the defect of early philosophy was that its universal was "the one beyond the many," not the "one in the many,"—in other words, that it was not a law or principle by which the particulars subsumed under it could be explained, but simply the abstraction of an element common to them. But the process of knowledge is a process that involves both analysis and synthesis, negation and reaffirmation of the particulars with which we start. If we exaggerate the former aspect of it, we enter upon the *via negativa* of the mystics, the way of pure abstraction and negation, which would open the mind to the ideal reality of things simply by shutting it to all the perceptions of sensible phenomena. And, if we follow out this method to its legitimate result, we must treat the highest abstraction, the abstraction of Being, as if it were the sum of all reality, and the Neo-Platonic ecstasy in which all distinction, even the distinction of subject and object, is lost as the only attitude of mind in which truth can be apprehended.

In the philosophy of the Socratic school we find the first attempt at a *systematic* as opposed to an *abstract* theory—the first attempt to bring together the one and the many, and so to determine the former that it should throw light upon the latter. Yet even in Plato the tendency to oppose the universal to the particular is stronger than the tendency to relate them to each other, and in some of his dialogues, as, *e.g.*, in the *Phædo*, we find a near approach to that identification of the process of knowledge with abstraction which is the characteristic of mysticism. Aristotle, therefore, had some ground for taking the Platonic principle that "the real is the universal" in a sense which excludes the reality of the individual. Yet, though he detected Plato's error in opposing the universal to the particular, and though, at the same time, he did not entirely lose sight of the truth which Plato had exaggerated, that the particular is intelligible only *through* the universal, Aristotle was not able to escape the influence of that dualism which had marred the philosophy of his predecessor. Hence the effect of his protest against a philosophy of abstraction was partly neutralized by his separation between the divine Being as pure form and nature as the unity of form and matter, and again by his separation of the pure reason which apprehends the forms of things from the perceptions of sense which deal with forms realized in matter. And after Aristotle's time the tendency of philosophy was more and more to withdraw from contact with experience. The Neo-Platonic philosophy, and the Christian theology which was so strongly influenced by it, contained, indeed, an idea of the reconciliation of God and nature, and hence of form and matter, which must ultimately be fatal to dualism, and therefore to the method of mere abstraction. But the explicit meaning of the philosophy of the Middle Ages was still dualistic, and the mode in which the Aristotelian formulæ were wrought into the substance of Christian doctrine by the scholastics tended more and more to conceal that idea of the unity of opposites which was involved in Christianity. Hence mediæval realism presented, in its most one-sided form, the doctrine that "the real is the universal," meaning by the universal nothing more than the abstract. And, as a natural consequence, the modern insurrection of the scientific spirit against scholasticism took its start from an equally bald and one-sided assertion of the opposite principle, that "the real is the individual," meaning by that the individual of immediate perception. If Platonism had dwelt too exclusively on one aspect of the process of knowledge, viz., that it seeks to rise above the particular, the sensible, the subjective, to the universal, the intelligible, the objective, as if in the latter alone were reality to be found, modern men of science learnt from their first nominalistic teachers to regard the universal as nothing more than an abbreviated expression for the particulars, and science itself as a mere generalization of the facts of sensible perception. But this view of scientific knowledge, as a mere reaffirmation of what is immediately given in sense, is as imperfect as the opposite theory, which reduces it to the mere negation of what is so given. An ideal world utterly and entirely divorced from the phenomenal, and an ideal world which is simply a repetition of the phenomenal, are equally meaningless. The processes of science have both a negative and a positive side; they involve a negation of the particular as it is immediately presented in sense, but only with a view to its being reaffirmed with a new determination through the universal. The fact as it is first presented to us is not the fact as it is; for, though it is from the fact as given that we rise to the knowledge of the law, it is the law that first enables us to understand what the fact really means. Our first consciousness of things is thus, not an immovable foundation upon which science may build, but rather a hypothetical and self-contradictory starting-point of investigation, which becomes changed and transformed as we advance.

The nominalism of scientific men in modern times is due to two special causes, one of which has already been mentioned. It is partly due to the traditions of a time when mediæval realism was the great enemy of science. The Baconian protest against the "anticipation of nature" was a relative truth when it was urged against a class of writers who supposed that true theories could be attained without regard to facts; the Baconian assertion of the necessity of attending to *axiomata media* was the necessary correction of the tendencies of mystics, who supposed that philosophy could attain its end by grasping at once at absolute unity, and contented themselves, therefore, with a unity which did nothing to explain the differences. But, when the former was turned into the dogmatic assertion that the mind is, or ought to be, passive in the process of knowledge, as having in itself no principle for the explanation of things, and when the latter was turned into the dogmatic assertion that science can only proceed from part to part and never from the whole to the parts, these relative truths became a source of error. And this error was confirmed and increased by the mistaken views of those who first tried to correct it. For these, admitting that scientific truth is entirely derived from external experience, only ventured to assert the existence of *a priori* knowledge alongside of, and in addition to, that which is *a posteriori*. In other words, they sought in inner experience a basis for

those beliefs which outward experience seemed unable to support. But this basis was soon found to be treacherous. Introspection, observation of the inner life as opposed to and distinguished from the outer life, could be only an observation of the facts of the individual consciousness as such; and to base religion and morality on such a foundation was to treat God and right as subjective phenomena, which do not necessarily correspond to any objective reality. Nor was this conclusion really evaded by the assertion of the self-evidencing necessity of such ideas and beliefs, or of the principles upon which they are founded. For this necessity, as a subjective phenomenon, might be accounted for otherwise than by the supposition of their objective validity. Such scepticism, further, was favoured by the progress of science, which, as it advanced from physics to biology and sociology, became more and more inconsistent with the idea of an absolute breach between inner and outer experience, and narrowed the sphere which had been hitherto reserved for the former. Man, it was urged, is but a part in a greater whole, not exempted from the law of action and reaction which connects all parts of that whole with each other. His individual life contains only a few links in a chain of causation that goes back to a beginning and onward to an end of which he knows nothing. And, as Spinoza says, *vis qua unaquæque res in existendo perseverat a causis externis infinite superatur.* Hence to treat ideas which are only states of the individual consciousness as the explanation of the world, instead of treating them as phenomena to be explained by its relation to that world, seemed to be an absurdity. The particular beliefs and tendencies of the mind were to be regarded, not as ultimate facts in reference to which everything is to be interpreted, but rather as facts which are themselves to be referred to more general causes and laws. It thus appeared that the attempt to divide truth into an *a posteriori* and an *a priori* part, the latter of which should find its evidence in an inner experience as the former in an outer experience, is an illusive process. If the *a priori* is reduced to the level of the *a posteriori*, it becomes impossible to base on the *a priori* any beliefs that go beyond the range of subjective experience. If the self and the not-self are taken simply as different finite things, which we can observe in turn, their relations must be brought under the general laws of the connexion of finite things with each other; and the phenomena of mind must be treated, like the phenomena of matter, as facts to be accounted for according to these laws.

But this of itself indicates a way of escape both from the introspective theory and from the empiricism to which it is opposed. For it suggests the question—What is the source of those very laws which guide the procedure of science in accounting for facts, psychological facts among others? When a scientific psychologist of the modern school attempts to show how by habituation of the individual and the race the necessity of thought expressed in the law of causation was produced in the minds of the present generation of men, it is obvious that his whole investigation and argument presuppose the law whose genesis he is accounting for. A glaring instance of such circular reasoning is found in the writings of the most prominent representative of the school in the present day. Mr Spencer begins by laying down as a first postulate of science that necessity of thought must be taken as a criterion of truth. It is by the continual aid of this postulate that he constructs his system of nature, and finally his psychological theory of the development of consciousness in man. Yet the main object of this psychological theory seems to be to account for the very necessities with which the author starts. Obviously such a philosophy contains elements of which the author is imperfectly conscious; for it involves that mind is not only the last product but the first presupposition of nature, or, in other words, that in mind nature returns upon its first principle. But to admit this is at once to lift the conscious being as such above the position which he would hold as merely a finite part of a finite world. It is to assert that nature has an essential relation to a consciousness which is developed in man, and that in the growth of this consciousness we have, not an evolution which is the result of the action of nature as a system of external causes *upon him*, but an evolution in which nature is really "coming to itself," *i.e.*, coming to self-consciousness, *in him.*

Now it was Kant who first—though with a certain limitation of aim—brought this idea of the relativity of thought and being to the consciousness of the modern world. In the *Critique of Pure Reason*, thought, indeed, is not set up as an absolute *prius*, in relation to which all existence must be conceived, but it is set up as the *prius* of experience, and so of all existences which are objects of our knowledge. Experience is for Kant essentially relative to the conscious self; it exists through the necessary subsumption of the forms and matter of sense under the categories, as, on the other hand, the consciousness of self is recognized as essentially dependent on this process. On this view, the *a priori* and *a posteriori* factors of experience do not really exist apart as two separate portions of knowledge. If they are severed, each loses all its meaning. Perceptions in themselves are void; categories in themselves are empty. We do not look outwards for one kind of truth and inwards for another, nor do we even, by an external process, bring facts given as contingent under principles recognized as necessary; but the *a priori* is the condition under which alone the *a posteriori* exists for us. Even if it is allowed that the facts of inner and outer experience contain a contingent element or matter, given under the conditions of time and space, yet neither time nor space nor the facts of experience conditioned by them exist for us except as elements of an experience which is organized according to the categories.

This is the essential truth which Kant had to express. It is marred in his statement of it by the persistent influence of the abstract division between contingent matter given from without and necessary principles supplied from within, a division essentially inconsistent with the attempt to show that the contingent matter is necessarily subsumed under these principles, and indeed exists for us only as it is so subsumed. But Kant himself puts into our hands the means of correcting his own inadequacy, when he reduces the inaccessible thing in itself, which he at first speaks of as affecting our sensibility and so giving rise to the contingent matter of experience, to a noumenon (νοούμενον) which is projected by reason itself. The *Dialectic* exhibits the idea of thought as not only constituting finite experience but also reaching beyond it, though as yet only in a negative way. The mind is, on this view, so far unlimited that it knows its own limits; it is conscious of the defects of its experience, of the contingency of its sensible matter, and the emptiness and finitude of its categories; and by reason of this consciousness it is always seeking in experience an ideal which it is impossible to realize there. Thought measures experience by its own nature, and finds it wanting. It demands a kind of unity or identity in its objects which it is unable to find in the actual objects of experience. It is this demand of reason which lifts man above a mere animal existence, and forces him by aid of the categories to determine the matter of sense as a world of objects; yet, as this finite world of experience can never satisfy the demand

of reason, the consciousness of it is immediately combined with the consciousness of its limited and phenomenal character. The student of the *Critique of Pure Reason* cannot but recognize the strange balance between the real and the phenomenal in which it ends, allowing to man the consciousness of each so far as to enable him to see the defects of the other,—so that by aid of the pure identity of reason he can criticize and condemn the "blindness" or unresolved difference of experience, and by means of the concreteness and complexity of experience he can condemn the "empty" identity of reason.

In order, however, to understand the full bearing of Kant's criticism of knowledge, and at the same time to find the meeting-point of the opposite currents of thought which alternately prevail in it, it will be necessary to consider the subject a little more closely. The lesson of the *Critique* may be gathered up into two points. In the first place, it is a refutation of the ordinary view of experience as something immediately given for thought and not constituted by it. In the second place, it is a demonstration of the merely phenomenal character of the objects of experience, *i.e.*, the demonstration that the objects of experience, even as determined by science, are not things in themselves. Both these results require to be kept clearly in view if we would understand the movement of thought excited by Kant. On the one hand Kant had to teach that what is ordinarily regarded as real, the world of experience, is transcendently ideal, *i.e.*, is determined as real by *a priori* forms of thought. On the other hand he had to teach that the world so determined is empirically and not transcendentally real, *i.e.*, its reality is merely phenomenal. With the former lesson he met the man of science, and compelled him to renounce his materialistic explanation of the world as a thing which exists in independence of the mind that knows it. The world we know is a world which exists only as it exists *for us*, for the thinking subject; hence the thinking subject, the ego, cannot be taken as an object like other objects, an object the phenomena of which are to be explained like other phenomena by their place in the connexion of experience. Having, however, thus repelled scientific materialism by the proof that the reality of experience is ideal, Kant refuses to proceed to the complete identification of reality with ideality, and meets the claims of the metaphysician with the assertion that the reality of experience is merely phenomenal. Hence he rejects any idealism that would involve the negation of things in themselves beyond phenomena, or the identification of the objects of experience with these things. The reality we know is a reality which exists only for us as conscious subjects, but this, though it is the only reality we can know, is not the absolute reality.

It is, however, to be observed that the nature of this opposition between phenomena and things in themselves seems to change as we advance from the *Analytic*, where the existence of such things is presupposed, to the *Dialectic*, where the grounds of that presupposition are examined. At first the opposition seems to be between what is present in consciousness and what is absolutely beyond consciousness. The matter of experience is regarded as given externally in the affections of the sensible subject,—affections caused by an unknown thing in itself, of which, however, they can tell us nothing. On the other hand the form of experience, the categories and principles of judgment which turn these affections into objects of knowledge, are not pure expressions of the real nature, the pure identity, of the subject in itself, but only products of the identity of the self in relation to the sensibility and its forms of time and space. Hence, on both sides we must regard experience as merely phenomenal, alike in relation to the noumenal object and in relation to the noumenal subject, which lurk behind the veil and send forth into experience on the one side affections which become objects through their determination by the unity of thought, and on the other side an identity of thought which becomes self-conscious in relation to the objects so determined by itself.

Kant, however, having thus answered the question of the possibility of experience by reference to two things in themselves which are out of experience, is obliged to ask himself how the *consciousness* of these two things in themselves, and the criticism of experience in relation to them, is possible. And here, obviously, the opposition can no longer be conceived as an opposition between that which is and that which is not in consciousness. For the things in themselves must be present to consciousness in some fashion in order that they may be contrasted with the phenomena. If, therefore, phenomena are now regarded as unreal, it must be because we have an *idea of reality* to which the reality of experience does not fully correspond. In the *Analytic* Kant had been speaking as if the real consisted in something which is not present to the conscious subject at all, though we, by analysis of his experience, can refer to it as the cause of that which is so present. Now in the *Dialectic* he has to account for the fact that the conscious subject himself is able to transcend his experience, and to contrast the objects of it as phenomenal with things in themselves.

Now it is obvious that such an opposition is possible only so far as the thought, which constitutes experience, is at the same time conscious of itself in opposition to the experience it constitutes. The reason why experience is condemned as phenomenal is, therefore, not because it is that which exists for thought as opposed to that which does not exist for thought, but because it imperfectly corresponds to the determination of thought in itself. In other words, it is condemned as unreal, not because it is ideal, but because it is *imperfectly* ideal. And the absolute reality is represented, not as that which exists without relation to thought, but as that which is identical with the thought for which it is. In the *Dialectic*, therefore, the noumenon is substituted for the thing in itself, and the noumenon is, as Kant tells us, the object as it exists for an intuitive or perceptive understanding, *i.e.*, an understanding which does not synthetically combine the given matter of sense into objects by means of categories, but whose thought is one with the existence of the objects it knows. It is the idea of such a pure identity of knowing and being, as suggested by thought itself, which leads us to regard our actual empirical knowledge as imperfect, and its objects as not, in an absolute sense, *real* objects. The noumena are not, therefore, the unknown causes by whose action and reaction conscious experience is produced; they represent a unity of thought with itself to which it finds experience inadequate. This higher unity of thought with itself is what Kant calls reason, and he identifies it with the faculty of syllogizing. Further, he finds in the three forms of syllogism a guiding thread which brings him to the recognition of three forms in which the pure unity of reason presents itself to us in opposition to the merely *synthetic* unity of experience, a psychological, a cosmological, and a theological form. In each of these cases the empirical process of knowledge is accompanied, guided, and stimulated by an idea which nevertheless it is unable to realize or verify. In psychology we have ever present to us an idea of the identity of the self, which is never realized in our actual self-consciousness, because the self of which we are conscious is manifold in its states and because it stands in relation to an external world. The idea of simple identity is, therefore, something we may set

before us as the goal of an ideal psychology, to which we may approximate in so far as we can trace unity of faculty through all the differences of mental phenomena, but to which we can never attain owing to the nature of the matter with which we deal. Again, in our scientific attempts to explain our external experience, the unity of reason takes the form of an idea of the world as a completed infinite whole, which contains all the objects known to us and all other possible objects; but this cannot be realized in an experience which is conditioned by space and time, and is, therefore, ever incomplete. The idea of totality is, therefore, an *ideal*, which guides and stimulates our scientific progress, without which such a thing as science could not exist, but which at the same time can never be realized by science. Lastly, the unity of reason takes a third form in which identity and totality are combined,—as the idea of a unity in which all differences, even the difference of subject and object, are transcended,—the idea of a unity of all things with each other and with the mind that knows them. This idea also is one which science can neither surrender nor realize. It cannot surrender it without giving up that striving after unity without which science would not exist; and it cannot realize it, for the difference between the world, as it is presented to us in actual experience, and the subjective determination of our thinking consciousness cannot be overcome. We can, indeed, use the idea that the world is an organic whole, determined in relation to an end which consciousness sets for itself, as an *heuristic* principle to guide us in following the connexion of things with each other; but, as we cannot by means of any such idea anticipate what the facts of external experience will be, so we cannot prove that for a mind other than ours the unity of things which we represent in this way might not take a quite different aspect. Indeed we have reason to think it would; for, while we always think of a designing mind as using materials which have an existence and nature independent of the purposes to which they are put, the absolute mind must be conceived as creating the materials themselves by the same act whereby they are determined to an end. We must conceive it, in short, as an intuitive understanding for which end and means, objective and subjective, are one, or, in other words, as an intelligence whose consciousness of itself is or contains the existence of all that is object for it.

This new view of the things in themselves as *noumena* or ideals of reason involves a new attitude of thought towards them different from that dogmatic attitude which is provisionally adopted in the *Analytic*. Accordingly, we now find Kant speaking of them, not as things which exist independently of their being conceived, but as "problematical conceptions" of which we cannot even determine whether they correspond to any objects at all. They are "limitative" notions which have a negative value, in so far as they keep open a vacant space beyond experience, but do not enable us to fill that space with any positive realities. They are like dark lanterns which cast light upon the empirical world, and show what are its boundaries, but leave their own nature in obscurity. All that we can say of the noumenal self or subject is that it corresponds to the unity implied in all knowledge, but whether there is such a self, independent of the process of empirical synthesis and the self-consciousness which accompanies that process, we cannot tell. All that we can say of the noumenal reality of the objective world is that it corresponds to the idea of the objects of experience as a completed whole in themselves apart from the process whereby we know them, but whether there is any such real world independent of the process of experience it is impossible to say. Lastly, all that we can say of God is that He corresponds to the idea of the unity of all things with the mind that knows them,—an ideal which is involved in all knowledge,—but whether the realization of this idea in an intuitive understanding is even possible we have no means of determining, however we may suspect that understanding and sensibility are "branches springing from the same unknown root." The *Criticism of Pure Reason* ends, therefore, in a kind of seesaw between two forms of consciousness—a thinking consciousness, which transcends experience and sets before us an idea of absolute reality, but which cannot attain to any knowledge or even certitude of any object corresponding to this idea, and an empirical consciousness, which gives us true knowledge of its objects, but whose objects are determined as merely phenomenal and not absolutely real.

The equipoise thus maintained between the empirical and the intelligible world is, however, in the *Critique of Practical Reason*, overbalanced in favour of the latter. What the theoretical reason could not do "in that it was weak through the flesh," through its dependence on the very empirical consciousness which it sought to transcend, is possible to the practical reason, because it is primarily determined by itself. In our moral consciousness we find ourselves under a law which calls upon us to *act* as beings who are absolutely self-determined or free, and which, therefore, assures us that our intelligible self is our real self, and conclusively determines our empirical self in contrast with it as phenomenal. Thus the moral law gives reality to the intelligible world; or, as Kant expresses it, "the idea of an intelligible world is a point of view beyond the phenomenal which the reason sees itself compelled to take up, in order to think of itself as practical." In other words, the moral law presupposes freedom or determination in the rational being as such, and makes him regard himself, not merely as a link in the chain of conditioned existences in time and space, but as the original source of his own life. The blank space beyond the phenomenal thus begins to be filled up by the idea of a free causality which again postulates a world adequate and conformable to itself. And the man who, as an empiric individuality, is obliged to regard himself merely as an individual being determined by other individual beings and things is authorized as a moral being to treat this apparent necessity as having its reality in freedom, and to look upon himself as the denizen of a spiritual world where nothing is determined for him from without which is not simply the expression of his own self-determination from within. "Thus we have found, what Aristotle could not find, a fixed point on which reason can set its lever, not in any present or future world, but in its own inner idea of freedom,—a point fixed for it by the immovable moral law, as a secure basis from which it can move the human will, even against the opposition of all the powers of nature."[1] Starting from this idea of freedom, therefore, Kant proceeds to reconstruct for *faith* the unseen wor[ld] which in the *Critique of Pure Reason* he had denied as object of *knowledge*. Nor is he content to leave t[he] two worlds in sharp antithesis to each other, but even [in] the *Critique of Practical Reason*, and still more in t[he] *Critique of Judgment*, he brings them into relation to ea[ch] other, and so gives to theoretical reason a kind [of] authority to use for the explanation of the phenome[nal] world those ideas which of itself it might be inclined [to] regard as illusive.

In all this, however, it is difficult to avoid seeing [a] partial retractation of Kant's first views as to the irreconcila[ble] opposition of the phenomenal and the noumenal. For, [in] the first place, the moral imperative is addressed to a s[...]

[1] Kant, i. 638 (Rosenkranz's edition).

which is at one and the same time regarded in both characters, and which is called upon to subsume under the moral law acts which otherwise derive their character and meaning from the relations of the phenomenal world. That the particular nature of men as phenomenal individuals can be the means of realizing the universal law of reason is implied in all Kant's statements of the latter, and particularly in his conception of men as constituting together a "kingdom of ends"; for it is difficult to conceive this kingdom otherwise than as an organic unity of society, in which each individual, by reason of his special tendencies and capacities, has a definite office to fulfil in realizing the universal principle that binds all the members of the kingdom to each other. The *summum bonum*, again, is said to consist in the union of happiness with goodness, *i.e.*, of the empirical conditions of man's individual life as a sensible subject with the pure self-determination of the intelligible self; and God is postulated as a *Deus ex machina* to bind together these two unrelated elements,—a conception which shows the difficulty into which Kant has brought himself by defining them as unrelated. Still more obvious is the effort of Kant to get beyond the dualism of his first view of things in the *Critique of Judgment*. For in that work he maintains that the consciousness of the beautiful and the sublime is or involves a harmony of the understanding or the reason with sense; and, what is still more important, he points out that the idea of organic unity, without which we cannot explain the phenomena of life, contains in it a possibility of the reconciliation of freedom and necessity, of the intelligible and the phenomenal. This idea, he argues, we are authorized by our moral consciousness to apply to the whole course of the things in the phenomenal world, and so to regard it as a process to realize the moral ideal. No doubt he again partially retracts this view when he declares that we must treat the idea of final causality as merely a *subjective* principle of judgment, which, even in the case of living beings, is to be regarded only as necessary for us as finite intelligences. But such saving clauses, in which Kant recurs to the dualism with which he started, cannot hide from us how near he has come to the renunciation of it.

When we regard Kant in this way as asserting from one point of view an absolute limit which from another point of view he permits us to transcend, it becomes obvious that his philosophy is in an unstable equilibrium, which cannot but be disturbed by any one who attempts to develop or even to restate his ideas. Hence we need not wonder that those who take in earnest his denunciations of any attempt to transcend experience generally,—like Professor Huxley,—reject as worthless all Kant's later work; and that, on the other side, those who take in earnest his ideas of freedom, of organic unity, of an intuitive understanding, and of a *summum bonum* in which freedom and necessity meet together, are compelled to break through the arbitrary line which he drew between knowledge and belief. In favour of the former course it is easy in many places to appeal to the letter of Kant. In favour of the latter it need only be pointed out that, in Kant's view, all experience rests upon, or is in its development guided by, those ideas which yet he will not permit us to treat as sources of knowledge. Hence the principles of the *Critique* cannot legitimately be used against metaphysic, except by those who are prepared to admit the ideas of reason, up to the point to which he admits them, as ideas that limit and direct our experience,—while rejecting all use of them to cast light upon that which is beyond experience. In other words, they must maintain the possibility of a purely negative knowledge, of the knowledge of a limit by one who yet cannot go beyond it. They must show how we can have an ideal of knowledge which enables us to criticize experience without enabling us to transform it; they must show how ideas of the supersensible can so far be present to our thought as to make visible the boundaries of the prison of sense in which we are confined, without in any way enabling us to escape from it.

Is this possible? We may gather up the Kantian antithesis in the assertion that experience is the imperfect realization of an ideal of knowledge, derived from reason, with materials, derived from sense and understanding, the nature of which is such that they can never be brought into correspondence with the ideal. But this ideal, in all its three forms, as we have seen, is simply the idea of a pure unity or identity in which all differences are lost or dissolved—whether they be the differences of the inner or of the outer life, or finally the difference of inner and outer, subjective and objective, from each other. Kant's view therefore is, in effect, this, that thought carries with it the consciousness of an identity or unity, to which our actual experience in none of its forms fully corresponds. On the other hand, Kant does not hesitate equally to condemn the identity of thought as "empty" and subjective, because it does not contain in itself nor can evolve from itself the complex matter of experience. But this alternate condemnation of experience as unreal from the point of view of the ideas, and of the ideas as unreal from the point of view of experience, seems to show that *both* are unreal, as being abstract elements, which have no value save in their relation to each other, and which lose all their meaning when separated from the unity to which they belong. According to this view, ideas and experience, noumena and phenomena, if they are opposed, are also necessarily related to each other. If our empirical consciousness of the world of objects in space and time, as determined by the categories, does not correspond to the unity or identity of thought which is our ideal of knowledge, yet that idea of unity or identity is set up by thought in *relation* to experience, and cannot, therefore, be essentially irreconcilable with it. The two terms may be opposed, but their opposition cannot be absolute, seeing that they are in essential relation to each other. It is a great logical error not to discern that a negative relation is still a relation, *i.e.*, that it has a positive unity beyond it. This positive unity may not, indeed, be consciously present to us in our immediate apprehension of the relation in question, but it is necessarily implied in it. Now it is just because, in his separation of noumena and phenomena, Kant omits to note their essential relativity that he is forced to regard the former as a set of abstract identities of which nothing can be known, and the latter as the imperfect products of a synthesis which can never be completed or brought to a true unity. Yet the value of his whole treatment of the ideas of reason in relation to our intellectual and moral experience arises from the fact that in practice he does not hold to this abstract separation of the two elements. Ideas absolutely incommensurable with experience could neither stimulate nor guide our empirical synthesis; they could not even be brought into any connexion with it. When, therefore, Kant brings them into this connexion, he necessarily alters their meaning. Hence the pure abstract identity which excludes all difference is changed, in its application, into the idea of an organic unity, of which the highest type is found in self-consciousness, with its transparent difference of the subjective and objective self. It would be absurd and meaningless to say that science seeks to reduce experience to an abstract identity, in which there is no difference, unless for this were tacitly substituted what is really an entirely different proposition, that science seeks to find in the infinitely diversified world of space and time that unity in difference of which self-consciousness has in itself the pattern. It is in reference to the former kind

of identity—the abstract oneness of formal logic—that Kant proves that it is impossible for experience to be made adequate to ideas. But it is only of the latter kind of identity—the oneness of self-consciousness—that it can be said that it furnishes a guiding principle to scientific investigation or an ideal of knowledge. The same confusion is still more evident in Kant's account of our moral experience, in dealing with which he directly attempts to get synthetic propositions out of the pure identity of reason, in other words, to draw definite moral laws out of the logical principle of non-contradiction. Whatever success he attains is gained by substituting for the formal principle of *self-consistency* the positive idea of *consistency with the self*, and again by conceiving this self as a concrete individual, the member of a society, and so standing in essential relation to other selves. The pure abstraction from all the external results of action and from all motives of desire, which at the beginning of the *Metaphysic of Ethics* Kant declares to be essential to morality, is modified and indeed transformed, as we go on, by the admissions that other rational beings are *not* external to us in any sense that excludes their good from being an end of our endeavour, and that the desires are *not* irrational and immoral except in so far as they are directed to the pleasures of the sensuous individual (which in a conscious being they never entirely are). Both in the speculative and in the practical sphere, therefore, the absolute opposition of the ideal or noumenal to the empirical disappears, as soon as Kant attempts to apply it. For in both the abstract identity of formal logic, which is really the meaning of the noumenon as absolutely opposed to and incommensurable with experience, gives way to the unity of self-consciousness,—a unity which is so far from being *absolutely* opposed to the difference of the empirical consciousness that it necessarily implies it. For self-consciousness presupposes the consciousness of objects; though it is opposed to that consciousness, it is essentially correlated with it, and therefore its opposition cannot be regarded as absolute, or incapable of being transcended.

These considerations may throw some light on the relation of the *Analytic* and *Dialectic* of Kant, and on the nature of the opposition of noumenon and phenomenon as it is presented in the latter. In the deduction of the categories, Kant pointed out the essential relation of the objective world of experience to what he called the "transcendental unity of apperception"; *i.e.*, he pointed out that the unity of consciousness is implied in all its objects. This unity, he further showed, must be conceived as "capable of self-consciousness"; but it actually becomes conscious of self only in relation, though also in opposition, to the other objects determined by it. Now it is this consciousness of itself in opposition to other objects which is the source of Kant's "ideas of reason," of the dissatisfaction of the mind with its empirical knowledge, even in its scientific form, and of the demand for a higher kind of knowledge to which experience is not adequate. That a standard is set up for experience by which it is condemned is simply a result of the further development of that unity which is implied in experience—a result of the progress of thought from consciousness to self-consciousness, and of the contrast between the former and the latter. The problem with which Kant's *Dialectic* attempts to deal, and which it treats as insoluble, is, therefore, simply the problem of *raising consciousness to the form of self-consciousness*; in other words, of attaining to a knowledge of the world of experience as not merely a "synthetic," and therefore imperfect, unity of things external to each other, but as an organic unity of transparent differences, a self-differentiating, self-integrating unity, such as seems to be presented to us in pure self-consciousness. Nor can this problem be regarded as insoluble; for the unity of self-consciousness is identical with the unity of consciousness; it is only that unity become self-conscious. Hence the point of view at which consciousness and self-consciousness seem to be absolutely opposed to each other,—the highest point of view which Kant *distinctly* reaches,—can be regarded only as a stage of transition from the point at which their relative difference and opposition is not yet developed to the point at which they are seen to be the factors or elements of a still higher unity.

The later philosophy of Germany, from Kant to Hegel, is little more than the development of the idea just stated in its twofold aspect. In the first place, it is an attempt to show what is involved in the idea of thought or self-consciousness as in itself an organic whole, a many-in-one, a unity which expresses itself in difference, yet so that the difference remains transparent, and therefore is immediately recognized as expression of the unity. In the second place, it is an attempt to bridge over the difference between thought or self-consciousness and the external world of experience, and to show that this opposition also is subordinated to a higher unity. Or, to put it more directly, the idealistic philosophy of Germany seeks, on the one hand, to develop a logic or metaphysic which bases itself, not, like formal logic, on the idea of bare identity, but on the idea of self-consciousness; and, on the other hand, to show, in a philosophy of nature and spirit, how, by means of this logic, the opposition of thought to its object, or of the *a priori* to the *a posteriori* in knowledge, may be transcended. In the third and fourth sections of this article something more will be said of the manner in which this task was fulfilled. Here only a few words are necessary to sum up the results reached, and to give more distinctness to the new ideal of knowledge which those results suggest. We have seen that Kant's critical attitude involved two things,—on the one hand, the assertion that the existence we know is necessarily existence for thought, and, on the other hand, the denial that that which exists for our thought is absolute reality, a denial which again involves the presence to our thought of an ideal of knowledge, by which our actual knowledge is condemned. This ideal, however, was falsely conceived by Kant as an identity without any difference, and, in this sense, he does not hesitate to apply it even to self-consciousness itself. For, in a remarkable passage,[1] he attempts to prove that the consciousness of self is not a knowledge of the self, by a simple reference to the duality of the self knowing and the self known, arguing that the ego "stands in its own way," just because it exists only *for itself*, *i.e.*, because in knowing itself it presupposes itself. Kant evidently thinks that to know the real self it would be necessary to apprehend it in simple identity as purely an object without reference to a subject, or purely a subject without reference to an object. Yet to this it seems sufficient to answer that such an object or subject would lose its character as object or subject and become equivalent to mere being in general, and that, as such being is a mere abstraction, to know it cannot be the ideal of knowledge. If therefore there be a unity or identity of thought which is not realized in experience, and in reference to which we can regard experience as an imperfect form of knowledge, it cannot be found in this abstract identity of being. In truth, as we have seen, it is found in that very idea of self-consciousness which Kant is criticizing. Just because we are self-conscious, and therefore oppose the unity of the conscious self to the manifoldness of the world in space and time, do we seek *in* the world of space and time for a transparent unity which we cannot at first find there. But, when this is seen, we find in Kant himself the partial solution of the difficulty.

[1] *Kritik*, p. 279 (Rosenkranz's edition), *cf.* Hegel, v. p. 258.

Self-consciousness presupposes consciousness; for, while the apprehension of objects in consciousness is possible only in relation to the unity of the self, yet it is only in relation to and distinction from these objects that we are conscious of that unity. Hence the two opposites, self and not-self, are bound together, and presuppose a unity which reveals itself in their opposition, and which, when made explicit, must reconcile them. If, therefore, self-consciousness, in its first opposition to consciousness, gives rise to an ideal of knowledge to which our empirical knowledge of objects is inadequate, this arises from the fact that not only empirical knowledge but also the ideal to which it is opposed is imperfect, or that they both point to a unity which is manifested in their difference, and which is capable of containing and resolving it. In other words, the opposition of science to its ideal, which Kant has stated in his *Antinomies*, is not an absolute opposition, but one the origin and end of which can be seen.

This opposition reaches its highest point in the contrast between the transparent unity of self-consciousness, in which the difference of knower and known is evanescent, and the essential manifoldness and self-externality of the world in space, in which the differences seem to be insoluble. We must, indeed, think of self-consciousness as having life in itself and therefore as differentiating itself from itself; but this differentiation is held within the limit of its unity, it is a separation of movements which are separated only as they are united. On the other hand, the world in space presents itself as the sphere of external determination, in which things are primarily disunited and act only as they are acted on from without, and in which this external influence never goes so far as to destroy their reciprocal externality. In this sense it is that the opposition of mind and matter was taken by Descartes, and it is a survival of the same mode of thought that leads many even now to draw absolute lines of division between *a priori* and *a posteriori*, between ideas and facts, between spiritual and natural. Kant and Fichte give a new aspect to the difficulty by showing that the difficulty is one of reconciling consciousness and self-consciousness, and that in consciousness there is already present the unity which is manifested in self-consciousness, as, on the other hand, it is only through consciousness and in opposition to it that self-consciousness is possible. And Fichte made a further step when he attempted to show that the categories and the forms of perception, time and space, which Kant had taken as inexplicable facts, are implied in this contrast of consciousness and self-consciousness. The error that clings to Fichte's speculations is, however, that he treats consciousness merely as a necessary illusion which exists simply with a view to self-consciousness, and hence is led to regard self-consciousness itself—because it is essentially related to this necessary illusion—as a schema or image of an unknowable absolute. In fact, in the end Fichte falls back upon the abstract identity in which Kant had found his noumenon, and so ends his philosophy with mysticism. Even Schelling, though he saw that the absolute unity must be one that transcends the difference of self and not-self, did not finally escape the tendency to merge all difference in absolute oneness. On the other hand, it was the endeavour of Hegel to proceed in the opposite way,—not to lose self-consciousness or subjectivity in a mere unity of substance, but rather to show that the absolute substance can be truly defined only as a self-conscious subject. And just because he did this he was prepared to take a further step, and to regard the external world, not as Fichte regarded it, as merely the opposite of spirit, nor as Schelling regarded it, as merely the repetition and co-equal of spirit, but rather as its necessary manifestation or as that in and through which alone it can realize itself. His doctrine therefore might be summed up in two propositions,—first, that the absolute substance is spiritual or self-conscious, and, secondly, that the absolute subject or spirit can be conceived as realizing itself only through that very world of externality which at first appears as its opposite. In both respects Hegel's philosophy reverses the *via negativa* of mysticism, and teaches that it is only through the exhaustion of difference that the unity of science, of which the mind contains in itself the certitude, is to be realized. For mind or spirit, viewed in itself, is conceived as a self-differentiating unity, a unity which exists only through opposition of itself to itself. And it is but a necessary result of such a conception that spirit can fully realize its unity only through a world which in the first instance must present itself as the extreme opposite of spirit. Hence the process of thought in itself, which is exhibited in the logic, ends in the opposition to thought of a world which is its negative counterpart. And the "absolute spirit" of Hegel is thus, not pure self-consciousness, but that more concrete unity of self-consciousness with itself which it attains through and by means of this world.

The effect of this view upon the relation of metaphysic to science, which we are at present considering, is noticeable. It does not, as is often supposed, supersede science by an *a priori* construction of the universe, nor does it leave the results of science unchanged and simply provide for it a deeper foundation. The latter was the point at which Kant and Fichte stopped; for, while they showed the relativity of experience to the principle of self-consciousness, they conceived that the function of metaphysic is completed in showing the phenomenal character of the objects of science, and in reserving a free space beyond the phenomenal world for "God, freedom, and immortality." Schelling, on the other hand, as he did not adopt this merely negative view of the relation of spirit to nature or of *a priori* to empirical truth, was obliged to reinterpret the latter by the former. As, however, he did not recognize any distinctions which were not merely quantitative, he was led to apply the same easy key to every lock, and to think that he had explained all the different forms of existence, organic and inorganic, when he had merely pointed out a certain analogy between them. The metaphysic of Hegel, whatever may be said of the actual philosophy of nature produced by its author, contains no necessity for any such arbitrary procedure. In his *Logic*, indeed, he attempts to give us *in abstracto* the movement of thought in itself, from its simplest determination of being as qualitative or quantitative, through the reflective categories of substance and cause, up to its full consciousness of itself in its organic unity.[1] And in so doing he of course gives us an account of the various categories which science uses in the interpretation of nature. He further attempts to show that the highest categories of science are in themselves imperfect and self-contradictory,—in other words, that they mark a stage of thought which falls short of that unity of being and knowing after which science is striving, and which is the presupposition as well as the goal of all intelligence. But, while he does this, he clearly acknowledges two things,—on the one hand that nature is essentially different from pure self-consciousness, and that therefore logic can never by direct evolution of its categories anticipate the investigations of science, and, in the second place, that the final interpretation of nature through the highest categories presupposes its interpretation by the lower categories, and cannot be directly achieved without it. In other words,

1 This subject—the progress of thought from lower to higher categories and methods—will be more fully discussed in the third section.

science must first determine the laws of nature according to the principles of causality and reciprocity, ere philosophy can be in a position to discover the ultimate meaning of nature by the aid of higher principles. "The philosophy of nature," says Hegel, "takes up the material which physical science by direct dealing with experience has prepared for it at the point to which science has brought it, and again transforms this formed material without going back to experience to verify it. Science must, therefore, work into the hands of philosophy, in order that philosophy in its turn may translate the lower universality of the understanding realized by science into the higher universality of reason, and may show how in the light of this higher universality the intelligible world takes the aspect of a whole which has its necessity in itself. The philosophic way of looking at things is not a capricious attempt, once in a way for a change, to walk upon one's head after one has got tired of walking upon one's feet, or to transform one's work-a-day face by painting it over; but, just because the scientific manner of knowing does not satisfy the whole demand of intelligence, philosophy must supplement it by another manner of knowing."[1]

The result then may be briefly expressed thus. Kant and his successors showed the relativity of the object of knowledge to the knowing mind. He thus pointed out that the ordinary consciousness, and even science, are abstract and imperfect modes of knowing, in so far as in their determination of objects they take no account of a factor which is always present, to wit, the knowing subject. For *their* purposes, indeed, this abstraction is justifiable and necessary, for by it they are enabled within their prescribed limits to give a more complete view of these objects in their relation to each other than if the attempt had been made to regard them also in relation to the knowing subject. At the same time the scientific result so arrived at is imperfect and incomplete, and it has to be reconsidered in the light of a philosophy which retracts this provisional abstraction. For it must be remembered that the fact that science looks at things only in their relation to each other, and not to the knowing mind, narrows the points of view or categories under which it is able to regard them, or, in other words, limits the questions which the mind is able to put to nature. Just because science does not treat its objects as essentially related to the mind, it is unable to rise to what Hegel calls the point of view of reason, or of the "notion"; *i.e.*, it is obliged to treat objects and their relations merely under a set of categories, the highest of which are those of causality and reciprocity, and it is incapable of attaining to the conception of their organic unity. In other words, it is able to reach only a synthetic unity of given differences, and it cannot discover a principle of unity out of which the differences spring and to which they return. Now philosophy goes beyond science just because, along with the idea of the relativity of things to the mind, it brings in the conception of such a unity. Its highest aim is, therefore, not merely, as Kant still held, to secure a place for the supersensible beyond the region of experience, but to reinterpret experience, in the light of a unity which is presupposed in it, but which cannot be made conscious or explicit until the relation of experience to the thinking self is seen,—the unity of all things with each other and with the mind that knows them.

2. *Relation of Metaphysic to Psychology.*—It has already been shown that the doctrine that the thinking subject is presupposed in all objects of knowledge—or, in other words, that existence means existence for a conscious self—is not to be taken in a psychological sense. The idea that all science is based on psychology, and that, therefore, metaphysic and psychology are identical, cannot be retained by any one who has entered into the full meaning of the Kantian criticism. It is, however, so natural a misinterpretation of it, and it is so much favoured by the letter of the very book in which it was first decisively refuted, that it will be useful to point out more directly the fallacy involved in it, especially as this will place us in a better position to determine the true relation of the two parts of philosophy thus confounded.

The misunderstanding first took a definite form in the introduction to Locke's *Essay*, in which he proposes to provide against any undue application of the intellectual powers of man to problems which are too high for them, by first examining and measuring the powers themselves. Stated in this way, it is obvious that the proposal involves an absurdity; for we have nothing to measure with, except the very powers that are to be measured. To see round our knowledge and find its boundary, we must stand outside of it, and where is such a standing ground to be found? We cannot by knowing prescribe limits to knowledge, or, if we seem to be able to do so, it can only be because we compare our actual knowledge with some idea of knowledge which we presuppose. In this way the ancient sceptics—and modern writers like Sir W. Hamilton and Mr Spencer who have followed them—turned the duality involved in the idea of knowledge against its unity, and argued that, because we cannot know the object except as different from and related to the subject, we cannot know it as it is in itself. Obviously in this argument it is involved that in true or absolute knowledge the object must not be distinguished at all from the subject,—to which the easy answer is that *without* such distinction knowledge would be impossible. The sceptic argument, therefore, lands us in the unhappy case pictured in the German proverb: "If water chokes us, what shall we drink?" The object cannot be known if it *is* distinguished from the subject, and it cannot be known if it is *not* distinguished from the subject. Obviously the one objection is as good as the other, and both combined only show that the idea of knowledge involves distinction as well as unity, and unity as well as distinction. The sceptic insists on one of these characteristics to the exclusion of the other, and condemns our actual knowledge because it contains both. In Kant there is undoubtedly some trace of the same fallacy, in so far as the idea by contrast with which he condemns the objects of experience as phenomenal is the idea of an abstract identity without any difference; but we have seen that with him this abstract identity is on the point of passing into an altogether different idea—the idea of self-consciousness as the type of knowledge.

It appears, then, that the idea of measuring our powers before we employ them rests on a paralogism; for what is really meant is that we abstract one of the elements of the idea of knowledge, and then condemn knowledge for having other elements in it. It is possible to criticize and condemn special conceptions as not conforming to our idea of knowledge; but it is not possible to criticize the idea of knowledge itself; all we can do is to explain it. It is possible to see the limited and hypothetical character of certain of our ideas or explanations of things, because we are conscious that in developing them we have left out of account certain elements necessary to the whole truth; but this criticism itself implies, as the standard to which we appeal, a consciousness of truth and reality, a consciousness which we cannot further criticize. Here, therefore, we come upon what must seem to all who think it admissible to question the very possibility of knowledge an inevitable reasoning in a circle. We can answer objections only by means of the very idea which they dispute. But the

[1] Hegel, vii. p. 18.

answer is nevertheless a good one; for the objector also stands within the very circle which he seeks to break, and has no means of breaking it except itself. As soon as he speaks, he can be refuted by his own words; for his doubts also presuppose that unity of the intelligence and the intelligible world which he pretends to deny.

The error, however, cannot be fully corrected until we consider what gives it plausibility. The confusion of the metaphysical with the psychological problem is due to the fact that the being who is the subject of knowledge, for whom all exists that does exist, appears to be one, and only one, of the many objects of knowledge. When we say that existence means only an existence for a thinking self, we seem to be identifying the whole world with the feelings and ideas of men, *i.e.*, with certain phenomena that belong to the life of a class of beings which only forms a part of that world,—phenomena, moreover, that are not exactly the same in any two of that class of beings. If we are to escape this difficulty it is obvious that we must be able to separate the conscious self or subject, as it is implied in all knowledge, from the nature of man as a being who "though formally self-conscious" is yet "part of this partial world," *i.e.*, one of the objects which we know along with and in distinction from other objects, and in whom "the self-consciousness which is in itself complete, and which in its completeness includes the world as its object," is only progressively realized.[1] Metaphysic has to deal with conditions of the knowable, and hence with self-consciousness as that unity which is implied in all that is and is known. Psychology has to inquire how this self-consciousness is realized or developed in man, in whom the consciousness of self grows with the consciousness of a world in space and time, of which he individually is only a part, and to parts of which only he stands in immediate relation. In considering the former question we are considering the sphere within which all knowledge and all objects of knowledge are contained. In considering the latter we are selecting one particular object or class of objects within this sphere,—although no doubt it must make a great difference in our treatment of this object that we have to consider it as existing not only for us but for itself. If nature "becomes self-conscious in man," it is impossible to treat man *merely* as one among the other objects of nature. But it is not less true that he *is* one of those objects, and, in this point of view, the department of science and philosophy that deals with his life is as distinct from metaphysic—which deals with the conditions of all knowing and being—as is astronomy or physics. In both cases we have before us objects which we may consider in themselves apart from their relations to the conscious subject, and in both cases we must take cognizance of these relations if we would have a complete and final view of those objects. It is possible to have a purely objective anthropology or psychology—which abstracts from the relation of man to the mind that knows him—just as it is possible to have a purely objective science of nature. Such a natural science of man, however, will necessarily abstract at the same time from the fact that in man is manifested that universal principle in relation to which all things are and are known. In other words, it will omit that distinctive characteristic of man's being in virtue of which he is a subject of knowledge and a moral agent. Hence the abstraction in this case is more likely to lead to positive error, more likely to produce not only an imperfect but a distorted view of the object. Inorganic nature, if we take it *in itself*, is not untruly viewed, under the categories of causality and reciprocity, as a collection of objects externally determined by each other; the error lies only in taking it as if it could exist in itself. Even organic beings do not suffer much injustice in being brought under such categories; for, though, as living and still more as sensitive beings, they involve in themselves and in their relation to the world a kind of unity of differences to which the categories of external relation imperfectly correspond, yet they are not such unities *for themselves*, but only *for us*. In other words, the principle through which they are and are known is still external to them. Hence also they are determined by outward influences, though these influences act rather as stimuli to what we may call the self-determined movement of their own life than as mechanical or chemical forces which change it. But in man, in so far as he is self-conscious,—and it is self-consciousness that makes him man,—the unity through which all things are and are known is manifested; and therefore he is emancipated, or at least is continually emancipating himself, from the law of external influence. Nature and necessity exist for him as that from which his life starts, in relation to which he becomes conscious of himself, against which he has to assert himself, and in the complete overcoming of which lies the end of all his endeavour. Nature is the negative rather than the positive starting-point of his existence, the presupposition against which he reacts rather than that on which he proceeds; and, therefore, to treat him simply as a natural being is even more inaccurate and misleading than to forget or deny his relation to nature altogether. A true psychology must, however, avoid both errors: it must conceive man as at once spiritual and natural; it must find a reconciliation of freedom and necessity. It must face all the difficulties involved in the conception of the absolute principle of self-consciousness,—through which all things are and are known,—as manifesting itself in the life of a being like man, who "comes to himself" only by a long process of development out of the unconsciousness of a merely animal existence.

This problem first presented itself in a distinct form in the discussions of the Socratic school as to the nature of knowledge, discussions which turn mainly upon the relation of the conscious to the unconscious element in thought. Socrates, by his method more than by any direct statement, drew attention to the fact that all particular judgments in morals involve or presuppose a universal principle. At the same time he pointed out that, so far from this universal principle being known to those who are continually making such judgments, they are not even conscious of its existence. They constantly use general terms whose meaning they have never even thought of defining. The beginning of a rational life for them must therefore lie in their becoming conscious of their ignorance, *i.e.*, conscious that they have been all along judging, and therefore acting, on untested and even unknown assumptions. They must bring the unconscious universal to the light of day and define it, for until that is done it is impossible to live a moral, that is, a rational life. "Virtue is knowledge," *i.e.*, it is acting, not according to opinions, or particular judgments,—whose universal is unknown, and which therefore may be regarded as expressing merely the impulses or habits of the individual,—but in view of a universal principle determined by reason.

The onesidedness of this view—which absolutely condemns as vice all virtue that is not based on conscious principle—was partly corrected by another part of the doctrine of Socrates, who taught that knowledge is something that must be evolved from within the mind, and not merely communicated to it from without. For this implies that the moral principle may be present in men's minds, and may rule their thoughts and actions, long before they become directly conscious of it. They *are* rational although they have never thought about reason, and they

[1] Hume, vol. i. p. 131 (Green's edition).

do not wait for scientific ethics to judge and act morally, any more than they wait for logic to reason correctly. It is this line of thought which is universalized and mythically expressed by Plato in his doctrine of "reminiscence." According to this myth, we were conscious of ideas or universals in our pre-natal state; we forgot them in the shock of birth into this mortal life; but in feeling or sharing the rapture of the poet or the lover we recall them as identified or confused with individual objects which "are like them, or partake in them." The same explanation is given of the practical skill of the general and the statesman, and even of the "right opinion" which guides the ordinary good man. Such opinion is neither knowledge nor ignorance: not knowledge, for general principles or ideas are not in it present to the mind *as* ideas, and therefore the particular cannot be distinctly subsumed under them; yet not ignorance, for the ideas are after all present, though wrapped up in the particulars or confused with them. Nay, in the *Theætetus*, Plato endeavours to show that the pure particular without the universal, sensations without ideas, cannot enter into our consciousness at all, and that therefore the lowest point to which a conscious being can descend is "opinion," in which particular and universal, sensible and intelligible, are mingled together. In other words, no conscious being can apprehend the particular except through the universal, though that universal may be present only *in* consciousness and not *to* it. The task of philosophy is therefore only to make men "recollect themselves," *i.e.*, to make *self-conscious* that universality of thought in which all rational beings "partake," or which, in the language of later philosophy, constitutes reason. The imperfection of Plato's view lay, however, in this, that, while he clearly recognized that the condition of all consciousness of the particular is the universal, he did not see with equal clearness that the universal has a meaning only in relation to the particular. And this tendency to separate universal from particular is naturally accompanied by a tendency to set the subjective against the objective, and to regard the world, not as the manifestation of reason, but as a dualistic world, in which reason is chained to a lower principle—a world which can at best only give a hint or suggestion to the mind to enable it to recollect itself and recover for itself its own treasures. Thus the false method of introspection, the "high *priori* road" of mysticism, was at least opened up by Plato, if he did not altogether forsake the narrower and harder way to the spiritual world through nature and experience.

The great step in advance taken by Aristotle was due to his seeing the danger of this tendency. Those, however, who have maintained that Aristotle is the great *a posteriori* philosopher,—as Plato is the great *a priori* philosopher,—have entirely mistaken the bearing of Aristotle's criticism of the Platonic theory. As strongly as Plato does Aristotle maintain that reason is δυνάμει πάντα τὰ νοητά, and that, therefore, the apprehension of truth *by* the mind is not a mere external communication of it *to* the mind, but rather is the mind coming to a consciousness of itself. As firmly as Plato does he declare that truth in its highest form is self-evidencing, *i.e.*, that the principles of science, the laws of nature, when once they have been discovered, are seen to be true by their own light. His statements to this effect have been neglected or explained away, because they were supposed to be inconsistent with his still more frequently reiterated assertions that it is only from experience and by induction that the truth of things can be discovered. Writers of a later day,—who came to Aristotle with an idea of a fixed opposition between *a priori* and *a posteriori*, and who held that the only possible alternatives were *either* to divide knowledge between the two *or* to explain away one of them,—could not comprehend that Aristotle might be in earnest *both* in asserting that knowledge is derived from experience *and* in asserting that it is an apprehension by reason of that which is identical with itself and needs no extraneous evidence. But Aristotle started with no such fixed opposition. On the contrary, any one who reads the last chapter of the *Posterior Analytics* will see that he had no difficulty in maintaining that knowledge begins in the apprehension of τὸ καθ' ἕκαστον in sense perception, and that it proceeds from many perceptions to experience, and from many experiences to science; while at the same time he declared that the principles of science have their evidence in themselves. And the meaning of this declaration is shown in the *De Anima*, where we find him speaking of knowledge as the realization in the "passive reason" of man of an "active reason" which is eternal and unchangeable, and which in the consciousness of itself includes the knowledge of all things. Of this realization, indeed, there is in man only the potentiality or capacity, but just because this is a pure or universal capacity, because, as Aristotle puts it, it has no quality or determination of its own to stand between it and its objects, it is a capacity in which the absolute reason can realize itself, a capacity of knowing all things. Here we have Plato's myth of reminiscence freed from the metaphor of memory, and reduced to scientific terms; for that myth simply meant that the evolution of knowledge is the development of the mind to the consciousness of itself, and of all that is potentially in it. Only, by the combination of this doctrine with the idea of the necessity of induction, Aristotle at the same time guards against the purely subjective interpretation to which in Plato it was liable. For the process by which the mind "comes to itself" is conceived as a process by which at the same time it rises from the particular to the universal, from the γνώριμα ἡμῖν to the γνώριμα ἁπλῶς, from the bare apprehension of the facts of experience to the knowledge of them through their principles or laws.

Yet Aristotle was as little able as Plato to work out fully a theory of the relation between the universal and the individual reason; and the cause of this failure was in both cases substantially the same. In Plato's philosophy, the ideal tended to divorce itself from the phenomenal world in such wise that the latter was regarded only as suggesting or partaking in the former, but not as entirely explicable by it. It was not merely that, to the mind of the individual in its progress, the veil was only gradually lifted from the rationality of the world, but that in the world there was an irrational element from which the mind could save itself only by flight into the region of abstraction. And, though Aristotle by his doctrine of the essential relation of ideas to experience, or of the development of the mind to the acquisition of knowledge of the world, seemed to be on the way to correct this error, yet he too shrinks from regarding the phenomenal world as in itself intelligible. To him also an irrational matter mingles with things, and is in them a source of contingency and imperfection. Chance is not merely the reflexion upon the world of our imperfect knowledge, but a fact of experience, and there is therefore a region in which our best science cannot rise above generality to universality. In this way there remains for Aristotle an absolute *a posteriori*, a reality which cannot be understood, and which we can scarcely conceive as existing at all for the divine intelligence. At this point the Aristotelian philosophy appears to stand between two alternatives, either that, in the sense of pantheism, the finite world and its contingency is an illusion, or that it is contingent only for the growing intelligence of man, which fully understands neither itself nor the world which is its object. Aristotle, however, does not choose either horn of

the dilemma, and leaves us therefore with an unresolved dualism between thought and its object; and this again necessarily involves a dualism between the active reason, which, as he asserts, realizes itself in man, and the passive reason which constitutes his nature as a finite being.

In the Middle Ages the Platonic and Aristotelian idea that the apprehension of objective truth is one with the evolution of the mind to self-consciousness seemed to be entirely lost. Knowledge of the finite world was regarded as indifferent, and knowledge of the infinite was conceived to be something given on authority, and in reference to which the mind was confined to an attitude of passive reception or implicit faith. No greater slavery of the spirit can be conceived than that in which even the truths of religion and morality—the truths that regard the inmost life of the spirit itself—were taken as a lesson to be learned by rote from the lips of a teacher. Yet the consciousness that such truth, if it was to be received by the mind, still more if it was to transform the mind, could not be entirely foreign to it, found a voice in the scholastic philosophy. And the compromise or truce between faith and reason expressed in the saying of Anselm *credo ut intelligam*,—according to which reason was to confine itself to the analysis and demonstration of the data received in implicit faith from the church,—prepared the way for the recognition that the two are not essentially at variance. The mind that proceeds from *veneratio* to *delectatio*, from awe and submission to the doctrine to enjoyment and appreciation of it, must already in its awe and submission have the beginnings of an intelligent appreciation. Anselm's saying might be understood simply as meaning that we must have spiritual experience ere we can understand the things of the spirit. And in this sense it was adopted by the Reformers to express an idea almost the opposite of that with which the scholastics had associated it,—the idea that the direct apprehension of spiritual truth as entering into the inner life of the subject, as identified with his very consciousness of self, is the basis of all knowledge of it. In the Protestant church of the period after the Reformation, we find a growing tendency to insist on the subjectivity of religion, in the same exclusive and one-sided way in which the mediæval church had insisted on its objectivity. In some extreme representatives of Protestantism this went so far as to lead to a disregard, almost to a rejection, of all objective doctrine, and a reduction of theology to an account of the religious consciousness. On the other hand, while religion was thus made subjective, science claimed to be purely objective, and the followers of Bacon seemed to adopt towards nature the same attitude of passive receptivity which the mediæval Christian was taught to hold towards the church. While man was to learn everything from himself in religion, he was to learn nothing from himself in science. His aim must be to exclude subjective *idola*, in other words, to accept the facts as they were given, and keep himself out of the way. The inevitable result of this difference of view as to the nature of knowledge in these two different regions was, however, on the one hand a withdrawal of religion from all connexion with finite interests, and, especially from the attempt to connect religious principles with the knowledge of the finite world, and, on the other hand, an increasing tendency in those who represented finite science to regard religion as something merely subjective and even individual, as a feeling which could not be translated into thought or made the basis of any knowledge of the objective world.

The opposite principles of certitude which were thus set up for religious truth and truth of science need only to be brought together and contrasted to betray that they rest upon opposite abstractions, neither of which expresses the complete nature of truth or knowledge. On the one hand the truths of religion were maintained just because they were not, or were not merely, objective, but were capable of being tested by inner experience, and identified with the self-consciousness of the individual. On the other hand the truths of science were maintained because they were not, or were not merely, subjective, but were capable of being verified in objective experience. It was rightly seen on the one side that mere subjective feelings or opinions have no validity for any one but the subject of them, and on the other side that what is merely objective or externally given can have permanent value and interest for the intelligence only as it ceases to be mere isolated and unrelated fact—nay, that, even when science has discovered law and order in nature, it still wants the highest value and interest so long as that law and order are not seen as standing in essential relation to the intelligence itself. The idea of truth or knowledge as that which is at once objective and subjective, as the unity of things with the mind that knows them, enables us to understand the condemnation which the religious mind passed upon a merely external dogma, and even its lack of interest in a science which presented itself as an account of merely objective or external facts. And it enables us also to understand the way in which scientific men insisted upon objective fact as the basis of all knowledge, and the disrespect which they felt for a religion which seemed to admit that it had no such support. What is wanted to clear up the confusion on both sides is the growth of the perception among scientific men that the objectivity which they are seeking cannot be mere objectivity (which would be unmeaning), but an objectivity that stands in essential relation to the intelligence, and, on the other hand, the growth of the perception among religious men that the subjectivity of religion only means that God, who is the objective principle by whom things are, and are known, is spiritual, and can therefore be revealed to the spirit. When these two corrections have been made, it must become obvious that the religious consciousness is not the consciousness of another object than that which is present in finite experience and science, but simply a higher way of knowing the same object. And in this it is also involved that the two ideas of *a priori* and *a posteriori*, of that which is evolved from within and that which is given from without, are not essentially opposed to each other, but that the *a posteriori* is simply the first form of a consciousness which in its ultimate development must become *a priori*.

In that philosophy of compromise which was initiated by Descartes, one part of knowledge was regarded as innate, or developed from within, and another part as empirical, or imparted from without. In the second period of the history of modern philosophy this compromise was broken, and the names of Locke and Leibnitz—though with some hesitation on both sides—represent respectively the theories that all knowledge is *a posteriori* and that all knowledge is *a priori*. The compromise seemed to be renewed with Kant, but the form in which it was renewed pointed, as has been already shown, to something more than a compromise, for his doctrine was that the *a posteriori* element, the facts, exist for us only under *a priori* conditions, or, in other words, that what is usually called *a posteriori* is in part *a priori*. The criticism of this view need not be repeated. It is sufficient here to say that if, as Kant shows, the elements are inseparable or organically united, it is impossible to allege that so much belongs to the one and so much to the other. Furthermore, the consciousness of an essential difference in the elements of knowledge is possible only so far as that difference is transcended by the unity of knowledge. We can distinguish the *a priori* from the *a posteriori* only on condition that we can transcend

the distinction, and this means that the distinction itself is not absolute, but that there is a point of view from which the *a posteriori* may be regarded as *a priori*, and that which is given from without to the spirit may be referred to its own self-determined development.

Now it is just here that we come upon the turning-point of the philosophical controversy, in the form which it has taken in modern times. The problem may be expressed thus—In what sense can we apply the idea of development to the human spirit? Are we to treat that development as merely a determination from without, or as an evolution from within, or as partly the one and partly the other? In a sense all writers of the present day would admit that this last is the case. For, on the one hand, even the Darwinian theory accounts for development by aid of what we may call the *a priori* tendency of the individual to maintain itself in the struggle for existence, though it supposes that the condition or medium in which the individual is placed determines the direction in which that development proceeds. And, on the other hand, no one now would adopt the Leibnitzian theory that the individual is a monad, whose self-development is entirely conditioned by itself in such a sense that all the relations which it has to other existences are merely apparent, and that the coincidence of its life with the life of the world is the result of a pre-established harmony. On both sides, therefore, the idea of self-determination would be admitted, though the tendency of the Darwinians would be to regard this self-determination as something merely formal; and on both sides it would also be admitted that the self-determination does not exclude a determination from without, though extreme opponents of Darwin might be inclined to reduce this determination to a mere stimulus or external condition of the development of the nature of the subject to which the stimulus is applied. The question, however, remains whether, after all, this opposition of without and within is an absolute one, or whether there is any point of view from which it may be transcended. To Aristotle it seemed possible to answer this question in the affirmative, because he conceived that the reason of man is a pure or universal δύναμις, the evolution of which to complete self-consciousness is one with the process whereby the objective world comes to be known. Yet, as Aristotle admitted the existence in the world of a material principle which was essentially different from the ideal principle of reason, he was obliged to limit his statement as to the possible unity of the subjective and the objective consciousness, and to say merely that "in things *without matter* the knower is identical with the known." But this would immediately lead to the conclusion that the pure development of reason must be secured by abstraction from all finite and material objects, rather than by a thorough comprehension of them. The freedom of the spirit, on this theory, must be a negative and not a positive freedom, a freedom won, not by overcoming the world, but by withdrawing ourselves from its influence. It remained, therefore, for modern philosophy to work out the Aristotelian idea that the rational being as such, in spite of its necessary relation to and dependence on an external world, is never in an absolute sense externally determined. And, as we have already seen, the Kantian philosophy brought this problem within the reach of solution, in so far as it showed, first, that objective existence can have no meaning except existence for a thinking self, and, secondly, that existence for a thinking self means existence the consciousness of which is "capable of being combined with the consciousness of self." Add further to these propositions what was shown by Kant's successors, that that only can be combined with the consciousness of self which is essentially related to it, and we arrive at an idealistic theory of the world, which enables us at once to understand the relative value of the distinction between self-determination and determination from without, and at the same time to see that its value is only relative. If it be true that nothing exists which is not a possible object of consciousness, and again that there is no possible object of consciousness which is not essentially related to self-consciousness, then the phenomena of the external world, which at first present themselves under the aspect of contingent facts, must be capable of being ultimately recognized as the manifestation of reason; and the history of the conscious being in his relations with that world is not a struggle between two independent and unrelated forces, but the evolution by antagonism of one spiritual principle. It is, on this view, the same life which within us is striving for development, and which without us conditions that development. And the reason why the two terms, the self and the not-self, thus appear to be independent of each other, or to be brought together only as they externally act or react upon each other, lies in this, that the object is imperfectly known, and the subject is imperfectly self-conscious. This, however, does not make it less true that in self-consciousness is to be found the principle in reference to which the whole process may be explained, and therefore that the self-conscious subject, as such, lives a life which belongs to him, not merely as one object among others, but as having in himself the principle from which the life and being of all proceeds.

From this point of view, as has been already indicated, the relative value of a theory of human development, such as that which might be based on the ideas of Darwin, would not be denied. The conscious being may be regarded simply as an externally determined object, and the incorrectness of this assumption will not entirely destroy the value of the results attained, especially if, as is often the case with those who seek to construct a natural science of man, the assumption itself is not very strictly adhered to, but corrected by the tacit admission of other conceptions somewhat inconsistent with it. But, at the same time, it would require to be pointed out that such a science is necessarily abstract and imperfect, as it omits from its view the central fact in the life of the object of which it treats. It can do nothing to account for man's consciousness, or his capacity of becoming conscious, of the influences by which he is supposed to be determined; or, to put it from the other side, it takes for granted that the objects that influence man are intelligible objects, "capable of being combined with the consciousness of self," without seeing how much is involved in this assumption. Now it is evident that the consciousness of an influence cannot be explained by the influence itself, nor even by that taken together with the nature of the sensitive beings subjected to it. It is evident also that an influence mediated by consciousness is not, strictly speaking, an external influence, but that it is already transformed, and in process of being further transformed, by the development of the self to which it is present. For the dawn of consciousness, in which the external object first comes into existence for us as opposed to the self, is at the same time the beginning of the process by which its externality is negated or overcome. Self-consciousness is that which makes us individuals in a sense in which individuality can be predicated of none but a self-conscious being. For, in determining himself as a self, the individual at the same time excludes from himself every other thing and being, and determines them as external objects. He emancipates himself from the world at the same time that he repels the world from himself. Yet this movement of thought, by which his individuality is constituted, is also that by which he is lifted above mere individuality, for, in becoming conscious of self and not-self in their opposition and relation, he ceases to

be simply identified with the one to the exclusion of the other. His finite individuality is regarded by him from a universal point of view, in which it has no less and no more importance than any other individuality, or in which its greater or less importance is determined only by its place in the whole. On this universality of consciousness rests the possibility of science and of morality. For all science is just a contemplation of the world *in ordine ad universum* and not *in ordine ad individuum*; and all morality is just action with a view to an interest which belongs to the agent, not as this individual, but as a member of a greater whole, and ultimately of the absolute whole in which all men and all things are included.

In this nature of the conscious subject lies also the possibility of metaphysic in the sense of Aristotle, as that science which goes back to a πρῶτον φύσει, a beginning which is prior to the existence in consciousness of the individual self, and onward to an end in which the divisions of the finite consciousness are transcended,—as including, in short, ontology, or metaphysic in the narrower sense, on the one side, and theology, or the philosophy of religion, on the other. In truth, these two extremes of science are necessarily bound together: we can only go back to the beginning if we can go on to the end; we can only recover the first unity if we can anticipate the last. Or, to free the subject more definitely from the associations of time, we cannot apprehend the unity which is involved or presupposed in all the differences of our conscious life except in so far as we can look at our individual existence from the point of view of the whole to which it belongs. This will become evident if we consider the nature of the limits which have to be transcended by such a science. The individual conscious subject, as he finds himself at first, is but one being in a world that stretches out, apparently without limits, on every side of him. Of the things by which he is immediately surrounded he sees but a small part, and the influences which he receives from them are, as he knows, like the wave that breaks upon a shore from an unknown ocean, only the last partial expression of impulses that come from regions beyond his ken. Again, he finds himself as one in a changing series of beings, of which he knows only the last preceding terms, and he is aware that in a few years he, as one of this series, will cease to be. He is thus to himself a definitely limited being, and though his knowledge of himself and his world may be gradually widened so as to reach some little way back into the past, and anticipate a little of the future, or may go outwards in space to embrace a widening circle of existences around him, yet he always stops at a limit, of which he is conscious that it is no absolute limit, but simply an arbitrary halting-place where vision grows indistinct and imperfect. When he reflects upon himself from this point of view, he is forced to regard himself as but a fragment, and a fragment of an unknown whole, by which his whole being is determined to be what it is. His highest knowledge seems to be but a consciousness of his ignorance, his highest freedom a determination by motives the ultimate meaning of which is hid from him.

So far there seems to be no room for any metaphysical knowledge, any knowledge of ourselves and our world which is other than relative and *in ordine ad individuum*. But further reflexion shows that in this very consciousness of limit there is implied a consciousness of that which is beyond limit. While we proceed from part to part, beginning with ourselves and our immediate surroundings, and following out lines of connexion that lose themselves in the distance, we are guided by a consciousness of the whole as a unity through which the parts are determined. Nay, it is just the presence of this consciousness that makes us capable of what seems the piecework of our knowledge, in which, by the aid of the principle of causality, we connect particular with particular, and so gradually extend the sphere of light into the encompassing darkness. For that principle simply means that the limited external object does not sufficiently explain to us its own existence, and that therefore we are forced to explain it by a reference to something beyond it. It means, in other words, that we cannot rest in that which is not a self-bounded, self-determined whole. The application of the category of external determination has therefore an essential reference to the higher category of self-determination. The mere endlessness of space and time has no meaning except in opposition, yet in relation, to the true infinity of which we find the type in self-conscious thought. Or, to put it in the Kantian form in which it is already familiar to us, the consciousness of the objective world in space and time stands in essential relation to the unity of self-consciousness. And if when we regard the former exclusively we are forced to view ourselves as insignificant and short-sighted finite beings in an infinite universe, when we regard the latter we are enabled to see that in all this universe there is revealed only that spiritual principle which we find also in ourselves. In this way a new light is thrown on our first consciousness of ignorance. The strivings of our reason after knowledge can no longer be regarded as strivings after an unknown goal, but rather after a goal which it has prescribed for itself. The narrow limits of our individual life are not removed, but they cease to be for us the limits of a narrow circle of definition within a formless infinite. They become the limits of a sphere within a sphere, a sphere which is defined by the idea of knowledge or self-consciousness itself, and in which therefore, however we may wander, we are everywhere at home. In religious language, the sphere is not a mere universe, but God, who is without us only as He is within us, so that "by the God within we can understand the God without."

Again, as this consciousness takes man beyond his immediate existence, and enables him to determine it in relation to an absolute unity of all things in God, so it enables him to go back to a unity which is behind or prior to that existence. For, if the individual can look at himself as he looks at others, and at others as he looks at himself, *i.e.*, from a point of view which is unaffected by his individuality, and in which that individuality is for him only what it is for impartial reason, he can have nothing in him which binds his consciousness to his individuality as mere individuality; as therefore he can go beyond himself to apprehend the whole in which his individuality has a place, there is nothing to prevent him from going back upon himself, and upon the conditions which are prior to his own individual being. He is not tied to his immediate life, and can go below it just as he can rise above it.

"O God, I think Thy thoughts after Thee," said Kepler. In reading the "thoughts" written in the planetary system, Kepler was discovering the meaning of that which is simpler and more elementary than the existence of man, as a cycle of mechanical relations are simpler and more elementary than self-consciousness. Yet it was a true feeling that led him to connect this descent into the mechanical world with God. For it is only in virtue of the same faculty which enables us to rise to the absolute life which includes and subordinates our own that we can so free us from the image of our own conscious life as to apprehend and fix in thought the simpler relations of purely physical existence. But the same faculty of going back upon ourselves has a still deeper manifestation. Not only can we abstract from ourselves so as to understand the inorganic world, we can also abstract from ourselves so as to understand the conditions which are prior

view, the intelligence, in apprehending the indivisible unity of elements in the object, is at the same time apprehending the unity of the object with itself. The mind cannot be deceived in regard to that which forms a part of its consciousness of itself. In freeing the essential conception of the object from the contingency of matter, science has freed the object from that which made it foreign to intelligence, and the relation of thought to things ceases to be one of correspondence, and becomes one of identity.

The legitimate inference from this view of the relation of the intelligence to the intelligible world would seem to be that the partial separation of thought from its object and its imperfect correspondence with it is characteristic of our first empirical consciousness of things, and of the progress from that consciousness to science, but that in completed science the division ceases. The *esse* of things is not their *percipi*, but their *intelligi*. But, if this be taken as the truth, then it can no longer be supposed that the process by which scientific knowledge is attained consists simply in an analysis of the object as it is given in immediate perception. On the contrary, it must be held that, if our thought has to submit itself to the object, and to be brought into conformity with it, by a process of induction, it is equally true that in this process the object also must be changed, that it may be brought into conformity with the principle of thought. The genesis of science, according to this view, is not merely an analysis of given facts, but a process of vital transformation by which consciousness on the one side and the object on the other are brought into unity with each other. The idea, indeed, of an empty process, a process in which the activity of the mind is merely formal, is one which will not stand the slightest examination. A mind without categories, if such a thing were conceivable, would have no questions to ask in relation to the object presented to it, and could therefore get no answers. Those who make a pretence of approaching a subject in an absolutely receptive attitude, and without any presuppositions, only show that they are unconscious of the categories by which their thought is ruled; and they will be most slavishly guided by these categories just because they are unconscious of them. The schoolmen, when they applied their logical principles to the matter of Christian dogma, did not recognize that they were doing more than analysing and bringing out clearly the meaning of that dogma. But the effect of their work was to turn the system of divinity into a collection of insoluble puzzles; for the doctrine was a doctrine of reconciliation between divine and human, infinite and finite, universal and particular, and the principle of their method was to treat all these oppositions as absolute. In like manner it might be shown that the analysis of social phenomena which was made in the last century was inadequate and superficial, just because of the latent assumption of individualism on which it proceeded, and that the greater success of writers like Comte and Spencer does not arise merely or mainly from their being more careful observers of the phenomena of social life, but in great part from the fact that, rather by the unconscious movement of opinion than by any distinct metaphysic, their minds have become possessed by more adequate categories.

The idea that the process of thought is merely formal, or analytic of given matter, is, however, an error that has a truth underlying it. This is the truth expressed by Aristotle in his much misunderstood comparison of the intelligence of man to a *tabula rasa*, upon which nothing at first is written, and again in his assertion—already quoted—that the mind is a pure δύναμις, without any distinguishing quality of its own which could prevent it from apprehending the real nature of other things. In other words, self-conscious reason is not a special thing in the world, but the principle through which all things are, and are understood; and hence, as regards the distinction of things from each other, it is in the first instance undetermined and indifferent, and therefore open to be determined in one way or another, according to the object to which it is directed. But this simply means that the conscious subject, as such, is not bound to his own individuality, but can regard things, nay, in a sense, must regard them, from a point of view which is independent of it. This is what makes possible the self-restraint and self-abnegation prescribed to the scientific man, whose whole duty, as it is often said, is to keep himself out of the way and let the objects speak, to lay aside all subjective *idola* and prejudices that stand between him and the reality of things. This at first sight may seem to be equivalent to the assertion that the mind ought to be in a state of simple passivity or receptivity towards objects. What is really meant, however, is not that the intelligence should go out of itself, or cease to be itself, that it may know its object, but simply that it should show itself in its universality, or freedom from the limits of the individual nature. The self-abnegation of science is an endeavour, so to speak, to see the object with its own eyes, but this it can do only in so far as the consciousness for which the object is is that consciousness in relation to which alone all objects are, and are understood. Or, to put it in another form, the conscious self in its scientific self-abnegation does not give itself up to another, and become purely passive; it only gives up all activity which is not the activity of that universal thought for which and through which all things are. Hence, when it has so abnegated itself, its most intense constructive activity is just beginning, though, just so far as the self-abnegation has been real, that constructive activity has become one with the self-revelation of the object. As, however, it is only through the constructive activity of thought that there exists for us any object at all, so it is only through its continued activity that the conception of the object is changed, till it is completely revealed and known. And this activity involves a continuous synthesis, by which an ever wider range of facts is brought together in an ever more definite unity, until the mind has, if we may use the expression, exhausted its store of categories upon the world, and until the world has completely revealed itself in its unity with itself and with the mind.

To combine these two ideas—on the one hand that science begins in a self-abnegation by which the mind renounces all subjective prejudices, and thereby attains a purely objective attitude, and on the other hand that this purely objective attitude is not a mere attitude of reception, but one in which the mind is continually transforming the object by its own categories,—to see that the universality of the mind in knowing is not mere emptiness, and that its activity is synthetic just when it is most free from all presuppositions extraneous to the nature of its object,—is one of the greatest difficulties of the student of metaphysic. Universality at first looks so like emptiness, and a universal activity so like a merely formal activity, that it is no wonder that the one should be mistaken for the other. But if we make such a confusion, we may soon be forced to choose between a sensationalism that makes knowledge impossible and a mysticism which makes it empty. The pure identity of thought with itself which is involved in the process of analysis is put on the one side, and the manifold matter of experience which is the object of thought on the other, and between these opposites no mediation is possible. If we take our stand upon the latter, we are forced to reject all mental synthesis as invalid, because it involves a subjective addition to the

facts; if we take our stand on the former, we are compelled to regard all objective experience as irrational, because it does not correspond to the pure identity of thought.

In Aristotle's view of logic it cannot be said that this difficulty is clearly solved, though he seems to have seen the error of both extremes. On the one hand he often recognizes the synthetic character of the process of induction, as when he speaks of the universal idea or law as a central principle, in which we must find the key to all the difficulties suggested by different aspects of a given subject. Yet in other places we trace the influence of a merely analytic conception of that process as a process in which the universal is to be reached by abstracting from the peculiarities of individuals. And this conception of it is favoured by Aristotle's metaphysical theory, according to which the forms of things in the finite world are manifested in a resisting matter, a matter which prevents them from being perfectly or universally realized. For, in so far as this is the case, the facts will not be entirely explained by the knowledge of the form, and the knowledge of the form must be obtained, not by combining all the facts, but rather by abstracting from them. Again, in Aristotle's account of the process of thought in the *Prior Analytics*, he regards it as a formal deductive process; and, though in the *Posterior Analytics* he attempts to give a synthetic meaning to the syllogism by treating it as the method in which the properties of a thing may be proved of it, or combined with it, through its essential definition, yet this adventitious meaning bestowed upon the syllogistic process does not alter its essential nature. The ultimate source of this inadequate view of the process of thought seems to lie in Aristotle's imperfect conception of the unity or identity which is for him the type of knowledge. For, though, both in the *Metaphysic* and the *De Anima*, he defines that identity as self-consciousness or as a consciousness of objects which is identical with self-consciousness, yet he does not seem clearly to distinguish between a unity in which there is no difference and a unity in which difference is transcended and reconciled. This seems to be shown by his description of the principles which reason apprehends as *individua* or indivisible unities, rather than unities which imply, while they transcend, difference. Yet, in this definition of the unity of knowledge as self-consciousness, Aristotle has implicitly admitted that there is a duality or difference in the unity itself, and this might have been expected to modify his conception of the relation of consciousness to its objects. For, as self-consciousness is not simple like a chemical element, but only in the sense that it is an indissoluble unity of opposites, it might have been anticipated that one who had realized self-consciousness as the principle of knowledge would be able to regard the opposition between the consciousness of self and the consciousness of the world as itself also capable of being conceived as a unity.

This misconception of Aristotle may be shown in another way. In the *Metaphysic* we find him laying down what is called the logical law of contradiction as the ultimate principle of knowledge. The meaning of this principle, however, as Aristotle states it, is simply that thought in its essence is definition or distinction. If, as Heraclitus says, everything at once is and is not, if we cannot attach any definite predicates to things by which they may be distinguished from each other, then, as Aristotle argues, thought is chaos, and knowledge is impossible. If determination be not negation, if the assertion of A be not the negation of not-A, then there is no meaning in words. The criticism to be made on this view is obviously, not that it is a false statement of the law of thought, but that it is an imperfect statement of it. Thought is undoubtedly distinction; and, if all distinction be confounded, no meaning can be apprehended or expressed. But thought is also relation and connexion of the things distinguished, and this aspect of it is equally important with the other. Aristotle shows his one-sidedness—a one-sidedness which throws him into opposition to Plato, but which enables him to correct Plato only by falling into the opposite error—when he exclusively fixes his attention on the "differentiating" aspect of knowledge, and takes no notice of the "integrating" aspect of it. It is easy to see that this exclusive attention to one side of the truth may lead in many ways to a distorted view both of the world and of the intelligence that apprehends it. If Heraclitus be interpreted as simply denying the right of thought to introduce its definiteness into the flux of sense, nothing but absolute scepticism can come out of his philosophy; and Aristotle was right in maintaining that it is only as the flux is brought to a stand, and the universal is fixed as a permanent and definite object of thought,[1] that knowledge becomes possible. But, on the other hand, if distinction be taken as absolute, if the definite assertion of a thing be taken as a negation of all relation to what it is not, if the fixity of thought be taken as an abstract self-identity which excludes all the movement of finite things wherein they show their finitude and pass beyond themselves into other things, then knowledge will be equally impossible. Our consciousness, on such a theory, would be disintegrated into parts which would own no connexion with each other; nor would it be possible for us to think of things as, in spite of their differences, bound together into the unity of one world. The law of contradiction or distinction, therefore, is likely to lead to serious misconceptions, unless it be complemented by a law of relation—a law expressing the truth that there is a unity which transcends all distinction. For all intelligible distinction —all distinction of things in the intelligible world—must be subordinate to their unity as belonging to that world, and therefore essentially connected with each other and with the intelligence. In such a world, in other words, there can be no absolute distinctions or differences (not even between being and not-being); for distinction without relation is impossible, and a conception held in absolute isolation from all correlated conceptions ceases to have any meaning. This does not, of course, imply a negation of the law of contradiction within its own sphere, but it does imply that that sphere is limited, and that there is no absolute contradiction. All opposition is within a presupposed unity, and therefore points to a higher reconciliation, a reconciliation which is reached when we show that the opposition is one of correlative elements.

The great step in logical theory which was taken by the idealistic philosophy of the post-Kantian period was simply to dissipate the confusion which had prevailed so long between that bare or formal identity, which is but the beginning of thought and knowledge, and that concrete unity of difference, which is its highest idea and end. It was, in other words, to correct and complete the conceptions of thought as analytical, and as externally synthetical, by the conception of it as self-determining, to show that it is a unity which manifests itself in difference and opposition, yet in all this, even when it seems to be dealing with an object which is altogether external to it, is really developing and revealing itself. This new movement of thought might, in one point of view, be described as the addition of another logic to the logic of analysis and the logic of inductive synthesis which were already in existence. But it was really more than this; for the new logic was not merely an external addition

[1] ἠρεμήσαντος τοῦ καθόλου ἐν τῇ ψυχῇ, *An. Post.*, ii. 19.

to the old logics, it also put a new meaning into these logics by bringing to light the principles that were involved in them. At the same time it broke down the division that had been supposed to exist between logic and metaphysic, between the form or method of thought and its matter. It showed that thought itself contains a matter from which it cannot be separated, and that it is only by reason of this matter that it is able to ask intelligent questions of nature, and to get from nature intelligible answers. A short space must be devoted to explain this relation of the three logics to each other.

The analytic logic fairly represents our first scientific attitude to the world, in which we concentrate our attention upon the facts as they are given in experience, with no thought of any mental synthesis through which they are given. To ourselves we seem to have to do with an object which is altogether independent of our thought, and what we need in order to know it is to keep ourselves in a purely receptive attitude. All we can do is to analyse what is given, without adding anything of our own to it. It has, however, already been pointed out that this apparent self-abnegation is possible only because, in abnegating our individual point of view, we do not abnegate the point of view that belongs to us as universal or thinking subjects. In other words, the objectivity of knowledge thus attained is not the ceasing of the activity of our thought, but rather of all that interferes with that activity. We seem to abstract from ourselves, but what we do abstract from is only the individuality that stands between us and the world. The scientific observer who has thus denied himself, however, is not necessarily conscious of the meaning of what he has done. The immediate expression of his consciousness is not "I think the object," but "it, the object, is"; and the more intensely active he is the more his activity is lost for him in the object of it. His whole work is, for himself, only the analysis of given facts, and for the rest he seems to have nothing to do but to take the world as he finds it. The voice of nature to which he listens is for him not his own voice but the voice of a stranger, and it does not occur to him to reflect that nature could not speak to any one but a conscious self. His business is to determine things as they present themselves, to enumerate their qualities, to measure their quantities; and his logic accordingly is a logic governed by the idea of the relative comprehension and extension of the things which he thus names and classifies. Such an analytic logic seems to be all that is necessary, because the only predicates by which things are as yet determined are those which are involved in their presence to us in perception, and as perceived they seem to be at once given in all their reality to the mind that apprehends them.

A step is taken beyond this first naive consciousness of things, whenever a distinction is made between appearance and reality, or whenever it is seen that the things perceived are essentially related to each other, and that therefore they cannot be known by their immediate presence to sense, but only by a mind which relates that which is, to that which is not, immediately perceived. If "the shows of things are least themselves," we must go beyond the shows in order to know them; we must seek out the permanent for that which is given as transient, the law for the phenomenon, the cause for the effect. The process of thought in knowledge therefore is no longer lost in its immediate object, but is, partly at least, distinguished from it. For just in proportion as the reality is separated from the appearance does the knower become conscious of an activity of his own thought in determining things. From this point of view nature is no longer an object which spontaneously reveals itself to us, but rather one which hides its meaning from us, and out of which we must wring its secret by persistent questioning. And, as this questioning process obviously has not its direction determined purely by the object itself, it becomes manifest that the mind must bring with it the categories by which it seeks to make nature intelligible. To ask for the causes of things, or the laws of things, presupposes that the immediate appearance of them does not correspond to an idea of reality which the mind brings with it, and by which it judges the appearance. Nature is supposed to be given to or perceived by us as a multitude of objects in space passing through successive changes in time; and what science seeks is to discover a necessity of connexion running through all this apparently contingent coexistence and succession and binding it into a system. Science, therefore, seems to question nature by means of an idea of the necessary interdependence and connexion of all things, as parts of one systematic whole governed by general laws—an idea which it does not get from nature, but which it brings to nature. Hence the logic in which this process of investigation expresses its consciousness of itself will be a synthetic logic, a logic built on certain principles which are conceived to be independent of experience, and by the aid of which we may so transform that experience, so penetrate into it or get beyond it, as to find for it a better explanation than that which it immediately gives of itself. The *Posterior Analytic*, in which Aristotle brings in the idea of cause to vivify the syllogistic process, or supply a real meaning to it, may already be regarded as a first essay in this direction. And the theory of inductive logic, as explained by Bacon and his successors down to Mill, is a continuous attempt to determine what are the principles and methods on which experience must be questioned, in order to extract from it a knowledge which is not given in immediate perception.

It was, however, Hume who first brought into a clear light the subjectivity of the principles postulated in this logic, and especially of the principle of causality, which is the most important of them. In thus contrasting the subjectivity of the principles of science with the objectivity of the facts to which they are applied, it was his intention to cast doubt on the science which is based on the application of the former to the latter. The principles, he maintains, are not legitimately derived from the facts, therefore they cannot legitimately be used to interpret them. They are due to the influence of habit, which by an illegitimate process raises frequency of occurrence into the universality and necessity of law, and so changes a mere subjective association of ideas into an assured belief and expectation of objective facts. The answer given by Kant to this sceptical criticism of science involved a rejection of that very opposition of subjective and objective upon which it was based. Without necessary and universal principles, the experience of things as qualitatively and quantitatively determined objects, coexisting in space and passing through changes in time (or even the determination of the successive states of the subject as successive), would itself have been impossible. Hence necessity of thought cannot be derived from a frequent experience of such objects. It is true that the determination of things as permanent substances reciprocally acting on each other, according to universal laws, goes beyond the determination of them as qualified and quantified phenomena in space and time. But both determinations are possible only through the same *a priori* principle, and we cannot admit the former determination without implicitly admitting the latter. As, therefore, it is through the necessity and universality of thought that objects exist for us, even before the application to them of the principles of scientific induction, and as the application of those principles is only a further step in that *a priori* synthesis which is already involved in the perception of these objects, we have no reason for treating

the former kind of synthesis as objectively valid which does not equally apply to the latter.

This vindication of the principles of induction has, however, a further consequence, which was not clearly seen by Kant. It is fatal to the antithesis of the "given" and the "known," of what is perceived and what is conceived, of *natura materialiter spectata* and *natura formaliter spectata*, which he still admitted. For that antithesis really rested on the idea that there is no universal and necessary principle of determination of things involved in the apprehension of them as qualified and quantified phenomena in space and time. So soon, therefore, as it is seen that there is such a principle, and that the first determination of things as objects of perception is due to the same *a priori* synthesis which determines them in the second place as objects of experience, the ground for that contrast between reality and appearance on which the theory of induction rested is taken away. Kant, indeed, finds a new meaning for that contrast by interpreting it as referring, not to the opposition between things as they are given and things as they are known, but to a supposed opposition between things as they are given and known in experience and things as they are in themselves out of experience. This new antithesis of reality and appearance, however, only means that the former antithesis has broken down, and that therefore the ideal of knowledge based upon it has yielded to a new ideal. The so-called things in themselves are noumena, the objects of an intuitive or perceptive understanding, *i.e.*, objects in which the contrast of perception and conception, of given and known, is transcended. We can make Kant's theory consistent only by supposing him to mean that the conception of the world as a system of substances determining each other according to universal laws does not yet satisfy the idea of knowledge which reason brings with it. In other words, just as science from the point of view of necessary law found something wanting in the conception of the world as a mere complex of quantified and qualified phenomena in space and time, so philosophy, in view of a still higher ideal of knowledge, may condemn the conception of the world as a system of objects determined by necessary laws of relation as itself inadequate and imperfect. And we have seen that this higher ideal is that which is involved in the unity of self-consciousness. Unfortunately Kant was unable, as Aristotle had been unable, to distinguish this idea from the idea of an abstract identity in which there is no room for even a relative difference of perception and conception, and therefore the perceptive understanding was named by him only to be rejected.

If, however, we correct this inadequacy of Kant's statement, as his later works enable us partly to correct it, we see that it involves a new idea of knowledge and a new logic,—a logic governed by the idea of organic unity and development, just as the analytic logic had been governed by the idea of identity, and as the inductive logic had been governed by the idea of necessary law. For, if the unity of self-consciousness be our type of knowledge, truth must mean to us, not the apprehension of objects as self-identical things, distinguished from each other in quantity and quality, nor even the determination of such things as standing in necessary relations to each other. It must mean the determination of the world (and of whatever in it is in any sense an independent reality, so far as it is so independent) as a unity which realizes itself in and through difference, a unity which is indeed determined, but determined by itself. In a view of the world which is governed by this category, correlation must be reinterpreted as organic unity, and causation as development. Its logical method must be neither analytical nor synthetical, or rather it must be both at once, *i.e.*, it must endeavour to exhibit the process of things as the evolution of a unity which is at once self-differentiating and self-integrating, which manifests itself in difference, that through difference it may return upon itself. Further, as this logic arises simply out of a deeper consciousness of that which was contained in the two previous logics, so it first enables us to explain them. In other words, the advance from the analytic to the inductive logic, and again from the inductive to what may be called the genetic logic, may itself be shown to be a self-determined development of thought, in which the first two steps are the imperfect manifestation of a principle fully revealed only in the last step. The consciousness of self-identical objects, independent of each other and of thought, is thus only the beginning of a process of knowledge which reaches its second stage in the determination of these objects as essentially related to each other, and which finds its ultimate end in the knowledge of the correlated objects as essentially related to the mind that knows them. Or if, in this last point of view, things are still conceived as having a certain relative independence of the mind, it can only be in so far as they are in the Leibnitzian sense monads, or microcosms,—*i.e.*, in so far as they are self-determined, and so have, in the narrower circle of their individual life, something analogous to the self-completed nature of the world, when it is contemplated in its unity with its spiritual principle.

Such a genetic logic is inconsistent with any absolute distinction between the *a priori* and *a posteriori* element in knowledge. For here the *a priori* is not simply a law of necessary connexion to be applied to an external matter, but a principle of organic development, a principle which, from the very nature of it, cannot be applied to a foreign matter. To treat the world as organic is to apply to it a category which is inconsistent with its being something merely given or externally presented to thought. The relation of things to thought must itself be brought under the same category of organic unity which is applied to the relation of things to each other in the world, otherwise the externality of the world to the thought for which it is will contradict the conception of the world as itself organic. Hence the distinction of *a priori* and *a posteriori*, so far as it is maintained at all, must shrink to something secondary and relative. It can be maintained only as a distinction of thought from its object, which presupposes their ultimate unity. From this point of view logic may be said to deal with the *a priori*, in so far as it treats the general conditions and methods of knowledge without reference to any particular object. Logic must exhibit abstractly the process by which the intelligence establishes its unity with the intelligible world; or, to put it in another way, it must demonstrate that the being of things can be truly conceived only as their being for thought. It is limited to the *a priori*, in the sense that it ends with the idea that the *esse* of things is their *intelligi*, and does not consider how this real intelligence or intelligible reality manifests itself in the concrete world of nature and spirit.

In this sense logic cannot be separated from metaphysic if metaphysic be confined to ontology. They are simply two aspects of one science, which we may regard either as determining the idea of being or the idea of knowing. The process of knowing is never really a formal process; it always involves the application of certain categories, and these categories are simply successive definitions of being or reality. We cannot separate the category from the movement of thought by which it is evolved and applied, nor the transition from lower to higher categories from changes of logical method. Hence a logic divorced from metaphysic inevitably becomes empty and unreal, and a metaphysic divorced from logic reduces itself to a kind of dictionary of abstract terms, which are put in no living

relation to each other. For such a logic and such a metaphysic must rest on the assumption of an absolute division between being and thought, the very two terms the unity of which it must be the utmost object of both logic and metaphysic to prove and to produce.

4. *The Relation of Metaphysic to Philosophy of Religion.*—The possibility of a "first philosophy," as we have already seen, is essentially bound up with the possibility of what we may call a last philosophy. It is only in so far as we can rise above the point of view of the individual and the dualism of the ordinary consciousness—in so far, in other words, as we can have at least an anticipative consciousness of that last unity in which all the differences of things from each other and from the mind that knows them are explained and transcended—that we are able to go back to that first unity which all these differences presuppose. The life of man begins with a divided consciousness, with a consciousness of self which is opposed to the consciousness of what is not-self, with a consciousness of a multiplicity of particulars which do not seem to be bound together by any one universal principle. Such division and apparent independence of what are really parts of one whole is characteristic of nature, and in spirit it is at first only so far transcended that it has become conscious of itself. A conscious difference, however, as it is a difference in consciousness, is no longer an unmediated difference. It is a difference through which the unity has begun to show itself, and which therefore the unity is on the way to subordinate. And all the development of consciousness and self-consciousness is just the process through which this subordination is carried out, up to the point at which the difference is seen to be nothing but the manifestation of the unity. Just so far, therefore, as this end is present to us,—so far as we are able to look forward to the solution or reconciliation of all the divisions and oppositions of which we are conscious and to see that there is an all-embracing unity which they cannot destroy,—is it possible that we should look back to the beginning or first unity, and recognize that these divisions and oppositions are but the manifestations of it. Thus the extremes of abstractness and of concreteness of thought are bound up together. The freedom of intelligence by which we get rid of the complexity of our actual life, and direct our thoughts to the simplest and most elementary conditions of being and knowing, is possible only to those who are not limited to that life, but can regard it and all its finite concerns from the point of view of the infinite and the universal. In this sense it is true that religion and metaphysic spring from the same source, and that it is possible to vindicate the rationality of religion only on metaphysical principles. The philosophy of religion is, in fact, only the last application or final expression of metaphysic; and, conversely, a metaphysic which is not capable of furnishing an explanation of religion contradicts itself.

This last remark affords us a kind of criterion of a true metaphysic. Can it or can it not explain religion? If it cannot, it must be equally unable to explain its own possibility, and therefore implicitly it condemns itself. Thus a pantheistic system, which loses the subject in the absolute substance, cannot explain how that subject should apprehend the substance of which it is but a transitory mode, nor, on the other hand, can it explain why the substance should manifest itself in and to a subject. And the same criticism may be made on all theories in which the first or metaphysical unity is abstractly opposed to the manifoldness and contingency of things. Not only of Spinoza, but also of Kant, of Fichte, and even of Schelling, it might with some truth be said that their absolute is like the lion's den, towards which all the tracks are directed, while none come from it. It is essential that the first unity should be such as to explain the possibility of difference and division, for, if it is not, then the return to unity out of difference is made as accidental as the difference itself. When Aristotle represented the Divine Being as pure self-consciousness, pure form without matter, he found himself unable to account for the existence of any world in which form was realized in matter. When therefore he speaks of the process of the finite world by which it returns to God, and attributes to nature a will, which is directed to the good as its final cause, his theory seems to be little more than a metaphor in which the analogy of consciousness is applied to the unconscious. For, if the Divine Being is not manifested in the world, any tendency of the world to realize the good becomes an inexplicable fact. A similar difficulty is, as we saw, involved in Kant's confusion of the bare identity of understanding with the absolute unity of knowledge. Reducing the unity of self-consciousness to such a bare identity, Kant could not be expected to see, what Aristotle had not seen, that pure self-consciousness is essentially related to anything but itself. Hence the various attempts which he made in his ethical works and in his *Criticism of Judgment* to find a link of connexion between the noumenal and the empirical were necessarily condemned even by himself as the expressions of a merely regulative and subjective principle of knowledge. Even Fichte, who found in the thought, which is for him the *prius* of all existence, a principle of differentiation and integration which explained how self-consciousness in us should be necessarily correlative with the consciousness of a world, was unable to free himself from the Kantian opposition of a noumenal identity in which there is no difference to a phenomenal unity which is realized in difference. Hence by him also the return out of difference is regarded as an impossibility, or as a *processus in infinitum*, and the absolute unity as that which is beyond all knowledge and only apprehended by faith.

If we look to completely elaborated theories, and disregard all tentative and imperfect sketches, it may fairly be said that all that has as yet been done in the region of pure metaphysic is contained in two works, in the *Metaphysic* of Aristotle and the *Logic* of Hegel. And up to a certain point the lesson which they teach is one and the same, viz., that the ultimate unity which is presupposed in all differences is the unity of thought with itself, the unity of self-consciousness, and that in this unity is contained the type of all science, and the form of all existence; in other words, $I = I$ is the formula of the universe. The difference between these two works has, however, already been indicated. With Aristotle, because he neglects the essential relation of self-consciousness to consciousness, or of the conscious self to the world of objects in space and time, the unity of self-consciousness tends to pass, as it did pass with the Neo-Platonists, into a pure identity without difference. In the Hegelian logic, on the other hand, self-consciousness is interpreted as a unity which realizes itself through difference and the reconciliation of difference—as, in fact, an organic unity of elements, which exist only as they pass into each other. In other words, it is shown that the differentiating movement by which the subjective and the objective self are opposed and the integrating movement by which they are reunited are both essential. Hence we cannot think of the conscious self as a simple resting identity, but only as an active self-determining principle; nor can we think of its self-determination as a pure affirmation of itself, without any negation, but only as an affirmation which involves a double negation—an opposition of two elements which yet are essentially united. Each factor in this unity, in fact, is necessarily conceived as passing beyond itself into the other; the subject is subject only as it relates itself to the object, the object is

object only as it relates itself to the subject. It is this tension against each other of elements which yet are correlated and indissolubly united, this self-surrender to each other of elements which yet are maintained in their distinction, which constitutes the organic unity of thought in itself, and separates it from the mere abstract unity of mysticism. When, however, the concrete or self-differentiating character of the unity of self-consciousness is apprehended in this way,—so that it is impossible to confuse its indivisible unity with the simplicity of that which is one merely because it has no differences in it,—the problem of the relation of pure self-consciousness to the world in space and time ceases to be insoluble. Thought, as it is seen to have difference in itself, is no longer irreconcilable with the world of difference; nor is it necessary to introduce a foreign ὕλη to make their connexion intelligible. For, as thought is a principle of difference as well as of unity, of analysis as well as of synthesis, and as it cannot realize itself in its unity except through the utmost development of difference, abstract self-consciousness, with its transparent or merely ideal difference, cannot be its ultimate form. On the contrary, the consciousness of self is possible only in distinction from, and in relation to, a world of objects. In other words, the unity of the thinking subject presupposes, not merely the opposition of the subjective and the objective self, but also the opposition of the self in its pure self-identity to a world of externality and difference. The pure intelligence, which is the *prius* of all things, must not, therefore, be regarded—as Aristotle regarded it—as merely theoretical, but also as practical. It must be conceived as a living principle, a principle which only in self-manifestation can be conscious of itself, and to the very nature of which, therefore, self-manifestation is essential. In this way Hegel—just because he grasped the concrete character of the unity of thought in itself—was enabled to understand the necessary unity of thought or self-consciousness with the world, and to heal the division of physics from metaphysic, which Aristotle had admitted.

Schelling and others who have raised objections to the Hegelian method have specially directed their criticisms against this transition from logic to the philosophy of nature, from pure self-consciousness to the external world in space and time. In doing so, they have practically fallen back upon the Aristotelian theory, with its opposition of God, as pure form, to the finite world. But this in effect is to deny that "the real is the rational" or intelligible, and to introduce into the world, as the ground of its distinction from reason, a purely irrational or contingent element. A modern follower of Schelling's later positive philosophy only draws the necessary consequence from this view when he teaches the pessimist creed that the highest good is the negation or extinction of the finite. Nor can we wonder that the same writer who denies that the absolute self-consciousness is essentially related to or manifested in the world should proceed to reduce this self-consciousness to a mystic identity which comes out of itself and becomes self-conscious only by an inscrutable act of will. The fact, indeed, that those who deny the possibility of a rational transition from self-consciousness to the world are forced by the logic of their position to reduce self-consciousness to an abstract identity may be regarded as a kind of indirect proof that the principle of self-consciousness, truly conceived, does involve that transition. Another step in the same direction may be made if we consider how the Cartesian philosophy treated the same opposition, which it also regarded as absolute. By Descartes mind and matter, thought and extension, are defined as abstract opposites, every quality of each finding its contradictory counterpart in a quality of the other. Mind is a pure self-determined unity, which is as it knows itself and knows itself as it is, which has no discretion of parts or capacity of division or determination from without. Matter is essentially discrete or infinitely divided; it is a pure passivity; and all its determination comes to it from without. The world is therefore, as it were, "cut in two with a hatchet," divided into two unrelated existences, which are held together only by the will of God. Spinoza cuts the knot, and avoids the arbitrariness of this solution, by treating extension and thought as two attributes separated only in respect of our intelligence, but each expressing fully the absolute substance. And something like the same view has been revived in recent times, by writers like Lewes and Mr Spencer, who speak of feelings and motions as two opposite "aspects" of the same fact. When we ask, however, *for whom* these attributes or aspects are a unity, it becomes clear that the intelligence which is regarded as standing on one side of the dualism must also be taken as transcending it, and relating the two sides to each other. Moreover, the correspondence of the two attributes upon which Spinoza insists and their contrariety upon which Descartes insists, when taken together, give us the idea of a correlative opposition, *i.e.*, of an opposition of elements which yet are necessary to each other. If, therefore, they cannot be simply identified as Spinoza identifies them, yet they need no external bond such as Descartes introduces to combine them; for they cannot exist apart from each other. Their opposition is held within the limits of their unity, and is no absolute contradiction, but rather an opposition which exists only as it is transcended. In other words, it is an abstract opposition, *i.e.*, it is an opposition of elements which seem to be irreconcilable till it is observed that they are correlative, that each exists or has a meaning only as it relates itself to, or passes out of itself into, the other, and that each, held in its abstraction and separation from the other, loses all the meaning that it seemed to have. For, as in an organic body each member or organ lives only in tension against the others, yet only as continually relating itself to the others, so the utmost opposition of mind to matter, of the intelligence to the intelligible world, presupposes their unity, and is only the realization of it.

There is here, however, something more than an ordinary case of correlation, for in this unity of opposites mind appears twice, once as one of the opposites, and again as the unity which transcends the opposition. This ambiguity becomes most obvious in theories like that of Mr Spencer, who speaks of "two consciousnesses," which cannot be resolved into each other, but yet which strangely form inseparable parts of one and the same consciousness. What, however, is really involved in such a statement is that the external world, which in the first instance presents itself as absolutely opposed in nature to the subject whose object it is, is yet one with that subject, and that therefore the antagonism of mind to its object is only the last differentiation through which it realizes its unity with itself. In Hegel's language, that which presents itself as other than mind is *its* other—"an other which is not another," whose difference and opposition to itself it overreaches and overcomes. We must, therefore, regard the independence and externality of nature, its indifference, and even, as it seems, opposition, to the development of the moral and intellectual life of man, as merely apparent. For man, in this point of view, is not merely one natural being among others, but the being in whom nature is at once completed and transcended. If, therefore, at first he appears to stand in merely accidental and external relations to the other existences among which he finds himself, yet the whole process of his life—the process by which he comes to know the external world, and by which, reacting upon it, he makes it the means to the realization of an individual and

fortune at that period. Metastasio was now twenty. During the last four years he had worn the costume of abbé, having taken the minor orders without which it was then useless to expect advancement in Rome. His romantic history, personal beauty, charming manners, and distinguished talents made him fashionable. That before two years were out he had spent his money and increased his reputation for wit will surprise no one. He now very sensibly determined to quit a mode of life for which he was not born, and to apply himself seriously to the work of his profession. Accordingly he went to Naples, and entered the office of an eminent lawyer named Castagnola. It would appear that he articled himself as clerk, for Castagnola, who was a stern master, averse to literary trifling, exercised severe control over his time and energies. While slaving at the law, Metastasio did not wholly neglect the Muses. In 1721 he composed an epithalamium, and probably also his first musical serenade, *Endimione*, on the occasion of the marriage of his patroness the Princess Pinelli di Sangro to the Marchese Belmonte Pignatelli. But the event which fixed his destiny was the following. In 1722 the birthday of the empress had to be celebrated with more than ordinary honours, and the viceroy applied to Metastasio to compose a serenata for the occasion. He accepted this invitation with mingled delight and trepidation; for Castagnola looked with no favour on his clerk's poetical distractions. It was arranged that his authorship should be kept a profound secret. Under these conditions Metastasio produced *Gli Orti Esperidi*. Set to music by Porpora, it won the most extraordinary applause. The great Roman prima donna, Marianna Bulgarelli, called La Romanina from her birthplace, who had played the part of Venus in this drama, was so enraptured with the beauties of the libretto that she spared no pains until she had discovered its author. Asked point-blank whether he had not written the words of the successful play, Metastasio was obliged to answer, Yes! La Romanina forthwith took possession of him, induced him to quit his lawyer's office, and promised to secure for him fame and independence, if he would devote his talents to the musical drama. It was thus that the opera, already partially developed by the Cæsarean poet, Apostolo Zeno, attained perfection. The right man had been found for maturing this form of art which the genius of the age demanded, but which was still but incomplete. In La Romanina's house Metastasio became acquainted with the greatest composers of the day,—with Porpora, from whom he took lessons in music; with Hasse, Pergolese, Scarlatti, Vinci, Leo, Durante, Marcello, all of whom were destined in the future to set his plays to melody. Here too he studied the art of singing, and learned to appreciate the style of such men as Farinelli. His singularly pliant genius discerned the conditions which the drama must obey in order to adapt itself to music in the stage it then had reached. Gifted himself with extraordinary facility in composition, and with a true poetic feeling, he found no difficulty in producing plays which, while beautiful in themselves, judged merely as works of literary art, became masterpieces as soon as their words were set to music, and rendered by the singers of the greatest school of vocal art the world has ever seen. Reading Metastasio in the study, it is impossible to do him justice. Our only chance of rendering him a portion of his due is to approach these lyrical scenes—so passionate in their emotion, so cunningly devised for musical effect—with the phrases of Pergolese or Paesiello ringing in our ears, and to imagine how a Farinelli or a Caffariello voiced those stanzas which demand for their artistic realization the "linked sweetness long drawn out" of melodies as the Italian school developed them. In short, Metastasio is a poet whose poetry leapt to its real life in the environment of music. The conventionality of all his plots, the absurdities of many of his situations, the violence he does to history in the persons of some leading characters, his "damnable iteration" of the theme of love in all its phases, are explained and justified by music. He can still be studied with pleasure and profit. But our only chance of understanding the cosmopolitan popularity he enjoyed is by remembering that at least one half of the effect he aimed at has been irrecoverably lost.

Metastasio resided with La Romanina and her husband in Rome. The generous woman, moved by an affection half maternal half romantic, and by a true artist's admiration for so rare a talent, adopted him more passionately even than Gravina had done. She took the whole Trapassi family—father, mother, brother, sisters—into her own house. She fostered the poet's genius and pampered his caprices. Under her influence he wrote in rapid succession the *Didone Abbandonata*, *Catone in Utica*, *Ezio*, *Alessandro nell' Indie*, *Semiramide Riconosciuta*, *Siroe*, and *Artaserse*. These dramas were set to music by the chief composers of the day, and performed in the chief towns of Italy. Every month added to Metastasio's renown. But meanwhile La Romanina was growing older; she had ceased to sing in public; and the poet felt himself more and more dependent in an irksome sense upon her kindness. He gained 300 scudi (about £60) for each opera; this pay, though good, was precarious, and he longed for some fixed engagement. Abandoning himself gradually to despondent whims and fancies, it became clear that some change in his condition was desirable. And the opportunity for a great change soon presented itself. In September 1729 he received the offer of the post of court poet to the theatre at Vienna, with a stipend of 3000 florins. This he at once accepted. La Romanina unselfishly sped him on his way to glory. She took the charge of his family in Rome, and he set off for Austria.

In the early summer of 1730 Metastasio settled at Vienna in the house of a Spanish Neapolitan, Niccolò Martinez, where he resided until his death. This date marks a new period in his artistic activity. Between the years 1730 and 1740 his finest dramas, *Adriano*, *Demetrio*, *Issipile*, *Demofoonte*, *Olimpiade*, *Clemenza di Tito*, *Achille in Sciro*, *Temistocle*, and *Attilio Regolo*, were produced for the imperial theatre. Some of them had to be composed for special occasions, with almost incredible rapidity—the *Achille* in eighteen days, the *Ipermnestra* in nine. Poet, composer, musical copyist, and singer did their work together in frantic haste. The impress of the peculiar circumstances under which they were created is still left upon them, not only in negligence of style, but also in an undefinable quality which marks them out as products of collaboration. But what must always surprise us is that they should be as good as they are. Metastasio understood the technique of his peculiar art in its minutest details. The experience gained at Naples and Rome, quickened by the excitement of his new career at Vienna, enabled him almost instinctively, and as it were by inspiration, to hit the exact mark aimed at in the opera.

At Vienna Metastasio met with no marked social success. His plebeian birth excluded him from aristocratic circles. But, to make up in some measure for this comparative failure, he enjoyed the intimacy of a great lady, the Countess Althann, sister-in-law of his old patroness the Princess Belmonte Pignatelli. She had lost her husband, and had some while occupied the post of chief favourite to the emperor. Metastasio's liaison with her became so close that it was even believed they had been privately married. From his letters to his friend La Romanina, and to the great singer Farinelli, who reigned supreme at the court of Madrid, we learn the little details of the poet's life in

its wearisome monotony, and come to comprehend his character, at once generous and timid, selfish and amiable, prudent almost to excess of caution, and personally cold in contradiction with the fervour of his sentimental muse. The even tenor of this dull existence was broken in the year 1734 by the one dark and tragic incident of his biography. It appears that La Romanina had at last got tired of his absence. Little satisfied with his friendly but somewhat reticent communications, impatient to see him once again, inquisitive perhaps about the terms on which he lived with his new mistress, she resolved to journey to Vienna. Could not Metastasio get her an engagement at the court theatre? The poet at this juncture revealed his own essential feebleness of character. To La Romanina he owed almost everything as a man and as an artist. But he was ashamed of her and tired of her. He vowed she should not come to Vienna, and wrote dissuading her from the projected visit. The tone of his letters alarmed and irritated her. It is probable that she set out from Rome, but died suddenly upon the road. Nothing can be said for certain about her end, or about the part which Metastasio may have played in hastening the catastrophe. All we know is that she left him her fortune after her husband's life interest in it had expired, and that Metastasio, overwhelmed with grief and remorse, immediately renounced the legacy. This disinterested act plunged the Bulgarelli-Metastasio household at Rome into confusion. La Romanina's widower married again. Leopoldo Trapassi, and his father and sister, were thrown upon their own resources. The poet in Vienna had to bear their angry expostulations upon his ill-timed generosity, and to augment the allowances he made them.

As time advanced the life which Metastasio led at Vienna, together with the climate, told upon his health and spirits. From about the year 1745 onward he writes complainingly of a mysterious nervous illness, which plunged him into the abyss of melancholy, interfered with his creative energy, and constantly distressed him with the apprehension of a general breakdown. He wrote but little now, though the cantatas which belong to this period, and the canzonet *Ecco quel fiero istante*, which he sent to his friend Farinelli, rank among the most popular of his productions. It was clear, as his latest and most genial biographer, Vernon Lee, has phrased it, that "what ailed him was mental and moral ennui." In 1755 the Countess Althann died, and Metastasio was more than ever reduced to the society which gathered round him in the bourgeois house of the Martinez. He sank rapidly into the habits of old age; and, though his life was prolonged till the year 1782, very little can be said about it. On the 12th of April he died, bequeathing his whole fortune of some 130,000 florins to the five children of his friend Martinez. He had survived all his Italian relatives.

During the long period of forty years in which Metastasio may be almost said to have overlived his originality and creative powers his fame went on increasing. In his library he counted as many as forty editions of his own works. They had been translated into French, English, German, Spanish, even into Modern Greek. They had been set to music over and over again by every composer of distinction, each opera receiving this honour in turn from several of the most illustrious men of Europe. They had been sung by the best virtuosi in every capital, from Madrid to St Petersburg, from London to Constantinople. The critics of all nations vied in raising Metastasio's credit to the skies. There was not a literary academy of note which had not conferred on him the honour of membership. Strangers of distinction passing through Vienna made a point of paying their respects to the old poet at his lodgings in the Kohlmarkt Gasse. Letters of congratulation, adulation, sympathy, respect, condolence, poured in upon him. And yet, during the whole of this long period, he was gradually outliving the artistic conditions upon which that fame was really founded. It has been already pointed out that Metastasio cannot rank as a poet in the unqualified sense of that word, but as a poet collaborating with the musical composer and performer. His poetry, furthermore, was intended for a certain style of music—for the music of omnipotent vocalists, of thaumaturgical soprani. With the changes effected in the musical drama by Gluck and Mozart, with the development of orchestration and the rapid growth of the German manner, a new type of libretto came into request. Metastasio's plays fell into undeserved neglect, together with the music to which he had linked them. Farinelli, whom he styled "twin-brother," was the true exponent of his poetry; and, with the abolition of the class of singers to which Farinelli belonged, Metastasio's music suffered eclipse. It was indeed a just symbolic instinct which made the poet dub this unique soprano his twin-brother.

The musical drama for which Metastasio composed, and in working for which his genius found its proper sphere, has so wholly passed away that it is now difficult to assign his true place to the poet in Italian literary history. Compared with Shakespeare, or even with Racine, he hardly merits the title of a dramatist. His inspiration was essentially emotional and lyrical. Instead of creating characters, he created situations for the display of very varied feelings, for all the feelings in fact to which melody allies itself. But in doing this he showed a capable playwright's faculty. His personages act and react upon each other. Their characters, though not in harmony with history or fact, are clearly traced and cleverly sustained. Each of the dramatis personæ is an emotion incarnate and consistent, admirably fitted for musical effect and contrast. The clash and combat of passions are vividly presented, with the smallest possible expenditure of rhetoric, in the dialogues intended for recitative. The climax of emotion is cadenced in appropriate stanzas, with simple but effective imagery, at the close of each important scene. The chief dramatic situations are expressed by lyrics for two or three voices, embodying the several contending passions of the agents brought into conflict by the circumstances of the plot. The total result is not pure literature, but literature supremely fit for musical effect. Language in Metastasio's hands is exquisitely pure and limpid. Of the Italian poets, he professed a special admiration for Tasso and for Marini. But he avoided the conceits of the latter, and was no master over the refined richness of the former's diction. His own style reveals the improvisatore's facility. Of the Latin poets he studied Ovid with the greatest pleasure, and from this predilection some of his own literary qualities may be derived. The pedantic rules of Aristotelian poetics never touched an artist who felt his real vocation to be the interpretation of music. For historical propriety, for the psychology of character, for unity of plot, for probability of incident, he had a supreme disregard. It was indeed his merit to have discarded all these considerations. His poetry was the twin-sister of Italian melody, and he was right in trusting entirely to music and action on the stage to render his conceptions vital. What, therefore, he gained during his own lifetime, while the musical system to which he subordinated his genius was yet living, he has since lost when, as now, he must be studied by readers who have only a faint and dim conception of that perished art. For sweetness of versification, for limpidity of diction, for delicacy of sentiment, for romantic situations exquisitely rendered in the simplest style, and for a certain delicate beauty of imagery sometimes soaring to ideal sublimity, he deserves to be appreciated so long as the Italian language lasts.

There are numerous editions of Metastasio's works. That by Calsabigi, Paris, 1755, 9 vols. 8vo, published under his own superintendence, was the poet's favourite. Another of Turin, 1757, and a third of Paris, 1780, deserve mention. The posthumous works were printed at Vienna, 1795. The collected editions of Genoa, 1802, and Padua, 1811, will probably be found most useful by the general student. Metastasio's life was written by Aluigi, Assisi, 1783; by Charles Burney, London, 1796; and by others; but by far the most vivid sketch of his biography will be found in Vernon Lee's *Studies of the 18th Century in Italy*, London, 1880, a work which throws a flood of light upon the development of Italian dramatic music, and upon the place occupied by Metastasio in the artistic movement of the last century. (J. A. S.)

METCALFE, Charles Theophilus Metcalfe, Baron (1785–1846), a distinguished administrator, was born at Calcutta on January 30, 1785; he was the second son of Thomas Theophilus Metcalfe, then a major in the Bengal army, who afterwards became a director of the East India Company, and was created a baronet in 1802. Having been educated at Eton, where he read extensively, he in 1800 sailed for India as a writer in the service of the Company. After studying Oriental languages with success at Lord Wellesley's college of Fort William, he, at the age of sixteen, received an appointment as assistant to Lord Cowley, then resident at the court of Sindhia; in 1802 he became assistant in the office of the chief secretary; in 1803 he was transferred to that of the governor-general, and in 1806 to that of the commander-in-chief. On August 15, 1806, he became first assistant to the resident at Delhi, and in 1808 he was selected by Lord Minto for the difficult post of envoy to the court of Ranjit Sinh at Lahore; here,

on April 25, 1809, he successfully concluded the important treaty securing the independence of the Sikh states between the Sutlej and the Jumna. Four years afterwards he was made principal resident at Delhi, and in 1819 he received the appointments of secretary in the secret and political department, and of private secretary to the governor-general (Lord Hastings). From 1820 to 1823 Sir Charles (who succeeded his brother in the baronetcy in 1822) was resident at the court of the nizam, but in the latter year he was compelled by the state of his health to retire from active service; in 1825, however, he was so far restored as to undertake the residency of the Delhi territories. Two years afterwards he obtained a seat in the supreme council, and in February 1835, after he had for some time been governor of Agra, he, as senior member of council, provisionally succeeded Lord William Bentinck in the governor-generalship. During his brief tenure of office (it lasted only till March 28, 1836) he originated or carried out several important measures, including that for the liberation of the press, which, while almost universally popular, complicated his relation with the directors at home to such an extent that he withdrew from the service of the Company in 1838. In the following year he was appointed by the Melbourne administration to the governorship of Jamaica, where the difficulties created by the recent passing of the Negro Emancipation Act had called for a high degree of tact and ability. Sir Charles Metcalfe's success in this delicate position was very marked (see vol. xiii. p. 551), but unfortunately his health compelled his resignation and return to England in 1842. Six months afterwards he was appointed by the Peel ministry to the governor-generalship of Canada, and his success in carrying out the policy of the home Government was rewarded with a peerage shortly after his return in 1845. He died at Malshanger, near Basingstoke, September 5, 1846. See J. W. Kaye's *Life and Correspondence of Charles Lord Metcalfe*, London, 1854.

METELLUS, the name of the most important family of the Roman plebeian gens Cæcilia. They rose to distinction during the Second Punic War, and Nævius satirized them.

Quintus Cæcilius Metellus Macedonicus, prætor 148 B.C. in Macedonia, defeated Andriscus in two battles, and forced him to surrender. He then superintended the conversion of Macedonia into a Roman province. He tried unsuccessfully to mediate between the Achæan league and Sparta, but, when the Achæans advanced, he defeated them easily near Scarpheia; Mummius soon after superseded him, and returning to Italy he triumphed in 146. Consul in 143, he reduced northern Spain to obedience. In 131 censor with Q. Pompeius (the first two plebeian censors), he proposed that all citizens should be compelled to marry. He was a moderate reformer, and was considered the model of a fortunate man; before his death in 115 three of his sons had been consuls, one censor, and the fourth was a candidate for the consulship.

Quintus Cæcilius Metellus Numidicus, whose reputation for integrity was such that when he was accused of extortion the jury refused to examine his accounts, was selected to command against Jugurtha in 109 B.C. He subjected the army to rigid discipline, and aimed solely at seizing Jugurtha himself; he defeated the king by the river Muthul, and next year, after a difficult march through the desert, took his stronghold Thala. Marius, however, accused Metellus of protracting the war, and received the consulate for 107. Metellus returned to Rome and triumphed. Saturninus, whom as censor he tried to remove from the senate, passed in 100 an agrarian law, inserting a provision that all senators should swear to it within five days. All complied but Metellus, who retired to Asia. After Saturninus was killed, he returned, but died shortly after under suspicion of poison.

Quintus Cæcilius Metellus Pius, so called from his efforts to restore his father Numidicus, commanded in the Social War, defeating Q. Pompædius (88 B.C.). Sulla on departing gave him proconsular command over South Italy. When Marius returned, the soldiers, who had no confidence in Octavius, wished Metellus to command, but he refused. Metellus retired to Africa and afterwards to Liguria, resuming his former command on Sulla's return. In 86 he gained a decisive victory over Norbanus at Faventia. In Sulla's proscriptions he pleaded in favour of moderation. Consul in 80 with Sulla, he went to Spain next year against Sertorius, who pressed him hard till the arrival of Pompeius in 76. Next year Metellus defeated Sertorius's lieutenant Hirtuleius at Italica and Segovia, and joining Pompeius rescued him from the consequences of a check at Sucro. From this time Sertorius grew weaker till his murder in 72. Metellus had previously set a price on his head. In 71 he returned to Rome and triumphed. He was an upright man, of moderate ability.

Quintus Cæcilius Metellus Pius Scipio, son of Scipio Nasica, was adopted by the preceding. He was accused of bribery in 60 B.C., and defended by Cicero. In August 52 Pompeius procured him the consulate. Scipio in return supported Pompeius, now his son-in-law. On war being resolved on, Scipio was sent to Syria. His extortions were excessive, and he was about to plunder the temple of Artemis at Ephesus when he was recalled by Pompeius. He commanded the centre at Pharsalus, and afterwards went to Africa, where by Cato's influence he received the command. In 46 he was defeated at Thapsus; in his flight to Spain he was stopped by a corsair, and stabbed himelf. His connexion with two great families gave him importance; but he was selfish and licentious, and his violence drove many from his party.

Quintus Cæcilius Metellus Celer, prætor 63 B.C., was sent to cut off Catiline's retreat northward. Consul in 61, his personal influence prevented the holding of the Compitalia, which the senate had forbidden and the tribunes permitted. He opposed the agrarian law of the tribune L. Flavius, and stood firm even though imprisoned; the law had to be given up. He also tried, though fruitlessly, to obstruct Cæsar's agrarian law in 59. He died that year under suspicion of poison given by his wife Clodia.

METEMPSYCHOSIS, the transmigration of the soul, as an immortal essence, into successive bodily forms, either human or animal. This doctrine, famous in antiquity, and one of the characteristic doctrines of Pythagoras, appears to have originated in Egypt. This indeed is affirmed by Herodotus (ii. 123):—"The Egyptians are, moreover, the first who propounded the theory that the human soul is immortal, and that when the body of any one perishes it enters into some other creature that may be born ready to receive it, and that, when it has gone the round of all created forms on land, in water, and in air, then it once more enters a human body born for it; and this cycle of existence for the soul takes place in three thousand years."

Plato, in a well-known passage of the *Phædrus*, adapts, as was his wont, the Pythagorean doctrine to his myth or allegory about the soul of the philosopher. That soul, he says, though it may have suffered a fall in its attempt to contemplate celestial things, still is not condemned, in its first entrance into another form, to any bestial existence, but, according to its attainments, *i.e.*, to the progress which it has made in its aspiration for celestial verities, it passes, in nine distinct grades, into the body of some one destined to become a philosopher, a poet, a king, a general, a seer, &c.; or, if very inferior, it will animate a sophist or an autocrat (τύραννος). Plato extends the cycle of existence to ten thousand years, which is subdivided into periods of a thousand years, after the lapse of which the souls undergo

judgment, and are admitted to everlasting happiness or condemned to punishment.[1] It is after the period of a thousand years, he adds, that the human soul comes into a beast, and from a beast again into a man, if the soul originally was human.

Pythagoras, who was said to have travelled in Egypt,[2] brought this fantastic doctrine into Magna Græcia, and made it a prominent part of his teaching. He declared that he had himself been Euphorbus, the son of Panthus, in the time of the Trojan War, and had successively inhabited other human bodies, the actions of all which he remembered.[3] Closely connected with his theory of metempsychosis was his strict precept to abstain from animal food, even from eggs, from some kinds of fish, and (for some unknown, probably symbolical, reason) from beans.[4] There can be no doubt that the Egyptian custom of preserving the mummies of cats, crocodiles, and some other creatures had its origin in the notion that they had been inhabited by souls which might some day claim these bodies for their own. We cannot suppose that Plato or the later Greeks really believed in the transmigration of souls, though there are many allusions to it, generally of a somewhat playful character. Thus Menander, in the play called *The Inspired Woman*[5] (Θεοφορουμένη), supposes some god to say to an old man, Crato, "When you die, you will have a second existence; choose what creature you would like to be, dog, sheep, goat, horse, or man." To which he replies, "Make me anything rather than a man, for he is the only creature that prospers by injustice."

Absurd and fantastic as such a doctrine as metempsychosis appears at first sight to be, it was in reality a logical deduction from primitive ideas about the nature of the soul. It is necessary to explain these ideas (which have important bearings on other questions) in order to show that metempsychosis was almost a necessary corollary to the belief that the soul was the vital or animating principle,—that the one distinction between organic and inorganic was the existence in the former of a ψυχή.

The difference between a dead body and a living body —or rather, one principal difference—was that the living animal breathed; and it was observed that, as soon as the breath left the body, not only did warmth and motion cease, but the body began to decay. Life, therefore, was breath, an opinion tacitly expressed by the Greek and Roman vocabulary, *animus, anima* (ἄνεμος), ψυχή, πνεῦμα, *spiritus*. But breath is air, and air is eternal and imperishable in its very nature. Therefore the "soul," or portion of air which gave animation to the body, did not perish at the dissolution of the body, but it was returned to the element of which it was composed, and out of which it came. It followed that, from the countless millions of "souls" emancipated from bodies in all time, and still flitting about invisibly in space, the air must literally swarm with souls,—a doctrine taught by Pythagoras.[6] Hence, any creature, human or bestial, that first drew the breath of life, might, so to say, swallow a soul, *i.e.*, take in with the act of respiration the very same particles of air which had animated some former body. For, although the soul was air, and returned to its kindred element, it was supposed to retain a peculiar character in intelligence (φρόνησις), remembrance of the past, and knowledge and experience gained in some former existence. Any creature which first breathed might or might not inhale this or that soul, just as a net thrown into the water may catch this or that fish, or no fish at all. But if no "soul" was inhaled the creature was believed for that reason to die; and the different degrees of intelligence observed in different men and animals led to the notion that there must have been a difference in the souls that first animated them. Even the belief that the soul, especially near the time of dissolution from the body, could foretell future events was based on the notion of intelligence and consciousness resulting from experiences of the past.[7]

As all the science of modern times cannot say precisely what life is, nor how it first came upon this earth, it is not wonderful that so obvious, though wholly erroneous, an explanation should have presented itself to primitive man when first he began to inquire into the causes of things. The extension of life, by the same term ψυχή, to plants and apparently non-breathing things, which, however, had birth, growth, and death, was a development of a philosophic age, and we are not surprised to find Aristotle recognizing one form of life as *vegetable*, φυτικόν.[8] The irrational confusion of "soul" with sentient bodily functions, the attribution to spirits (εἴδωλα) of motion, speech, or other muscular and material action, though still common, while metempsychosis is derided or forgotten, is in reality, perhaps, a less excusable superstition.

The Romans inherited the doctrine of metempsychosis from Ennius, the poet of Calabria, who must have been familiar with the Greek teachings which had descended to his times from the cities of Magna Græcia. In his *Annals*, or Roman history in verse, Ennius told how he had seen Homer in a dream, who had assured him that the same soul which had animated both the poets had once belonged to a peacock, a story that might seem to indicate Indian traditions. The *Pavo Pythagoreus* and the *Somnia Pythagorea* are referred to by Persius and Horace, as well as by Lucretius.[9]

Theories suggesting element-worship naturally led to the notion that air and ether (upper air) were divine.[10] Hence every soul, as being but a portion of it, was in itself divine, and therefore immortal. We thus see that the doctrine of the immortality of the soul, whether attained by a sound or a vicious course of reasoning, was an inevitable conclusion for early thinkers. Pantheism taught that all the universe was pervaded by a divine mind, and Virgil cites the opinion of some, that the intelligence of bees was due to a portion of this universal mind residing in them, a view closely allied to the doctrine of metempsychosis.[11] A divine thing might be polluted, but not destroyed; hence the notion of purifying souls by airing them or burning away a material defilement is enlarged upon by Virgil in the sixth book of the *Æneid* (724 *sq.*). (F. A. P.)

METEOR, METEORITE. The term meteor, in accordance with its etymology (μετέωρος), meant originally something high in the air. It has been applied to a large variety of phenomena, most of them of brief duration, which have place in the atmosphere. Disturbances in the air are aerial meteors, viz., winds, tornadoes, whirlwinds, typhoons, hurricanes, &c. The vapour of water in the atmosphere creates by its forms and precipitations the aqueous meteors, viz., clouds, fogs, mists, snow, rain, hail,

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1 P. 249 A. Comp. Rev. xx. 2, 13; Virg., *Æn.* vi. 745, "Donec longa dies, perfecto temporis orbe, concretam exemit labem," &c.

2 Diogen. Laert., viii. 1, 3; Lucian, *Gallus*, § 18 *sq.*, where the doctrine of metempsychosis and the stories about the pre-existence of Pythagoras are wittily satirized.

3 Lucian, *Gallus*, §§ 4, 5; Diodor. Sic., x. §§ 9, 10; Hor., *Od.* i. 28, 10, "habentque Tartara Panthoiden iterum Orco demissum."

4 *Gallus*, 19, 38. For fanciful reasons for the prohibition of beans, see Lucian, *Vitarum Auctio*, § 5.

5 Frag. 222, Meineke.

6 Diogen. Laert., viii. 1, § 32, *εἶναι πάντα τὸν ἀέρα ψυχῶν ἔμπλεων.*

7 Diodor. Sic., xviii., § 1.

8 *Ethics*, lib. i. 13.

9 Pers., *Sat.* vi. 9; Hor., *Epist.* ii. 1, 52; Lucret., i. 124.

10 ὦ δῖος αἰθήρ, Prometheus exclaims, Æsch., *Prom.*, 88.

11 *Georg.* iv. 219—

His quidam signis, atque hæc exempla secuti,
Esse apibus partem divinæ mentis et haustus
Ætherios dixere; deum namque ire per omnes
Terrasque tractusque maris cælumque profundum.

&c. The effect of light upon the atmosphere and its contents causes certain luminous meteors, viz., rainbows, halos, parhelia, twilight, mirage, &c. Discussion of all these, and of like phenomena, belongs to METEOROLOGY (*q.v.*).

Another class of luminous meteors, known as shooting or falling stars, fireballs, bolides, &c., have their place in the upper parts of the atmosphere. But by reason of their origin from without they, and the aerolites or meteorites which sometimes come from them, belong properly to astronomy. The term meteor is often used in a restricted sense as meaning one of these latter phenomena. The present article will treat of them alone.

The most remarkable of the meteors (and the most instructive) are those which are followed by the falling of stones to the earth. These have since the beginning of the present century attracted so much attention, and the phenomena have been so frequently examined and described by scientific men, that they are very well understood. The circumstances accompanying the fall of stones are tolerably uniform. A ball of fire crosses the sky so bright as to be visible, if it appears in the daytime, sometimes even at hundreds of miles from the meteor; and if it appears in the night it is bright enough to light up the whole landscape. It traverses the sky, generally finishing its course in a few seconds. It suddenly goes out, either with or without an apparent bursting in pieces, and after a short period a loud detonation is heard in all the region near the place where the meteor has disappeared. Sometimes only a single stone, sometimes several are found. For some falls they are numbered by thousands. About three thousand were obtained from the fall of L'Aigle in 1803, scattered over a region about 7 miles long and of less breadth. A like number was obtained from the fall of Knyahinya on June 9, 1866. At Pultusk a still larger number were collected, scattered over a larger space, by a fall in January 1868. From the Emmet county (Iowa) fall, May 10, 1879, a similarly large number have been secured.

These meteors leave behind them in the air a cloud or train that may disappear in a few seconds, or may remain an hour. They come at all times of day, at all seasons of the year, and in all regions of the earth. They come irrespective of the phases of the weather, except as clouds conceal them from view.

Let us describe one or two of these meteors more in detail. On the evening of the 2d of December 1876, persons in or near the State of Kansas saw, about eight o'clock in the evening, a bright fireball rising from near where the moon then was in the western sky. It increased in brilliancy as it proceeded, becoming so bright as to compel the attention of every one who was out of doors. To persons in the northern part of the State the meteor crossed the southern sky going to the east, to those in the southern part it crossed the northern heavens. To all it went down near to the horizon a little to the north of east, the whole flight as they saw it occupying not over a minute.

The same meteor was seen to pass in nearly the same way across the heavens from west-south-west to east-north-east by inhabitants of the States of Nebraska, Iowa, Missouri, Wisconsin, Illinois, Michigan, Kentucky, Indiana, Ohio, Pennsylvania, and West Virginia. But besides this there were heard near the meteor's path, four or five minutes after its passage, loud explosions like distant cannonading, or thunder, or like the rattling of empty waggons over stony roads. So loud were these that people and animals were frightened. East of the Mississippi river these explosions were heard everywhere within about 60 miles of the meteor's path; and in Bloomington, Indiana, sounds were heard supposed to come from the meteor even at a distance of nearly 150 miles from it. Over central Illinois it was seen to break into fragments like a rocket, and over Indiana and Ohio it formed a flock or cluster of meteors computed to be 40 miles long and 5 miles broad. The sky in New York State was wholly overcast. Persons in Ohio and Pennsylvania, who from their situation could look over the cloud last, saw the meteor passing on eastward over New York. From many places in the State itself came accounts of rattling of houses, thundering noises, and other like phenomena, which at the time were attributed to an earthquake.

At one place in northern Indiana a farmer heard a heavy thud as of an object striking the ground near his house. The next morning he found on the snow a stone of very peculiar appearance weighing three-quarters of a pound, which from its character there is every reason to believe came from the meteor. By putting together the various accounts of observers, the meteor is shown to have become first visible when it was near the north-west corner of the Indian Territory, at an elevation of between 60 and 100 miles above the earth. From here it went nearly parallel to the earth's surface, and nearly in a right line, to a point over central New York. During the latter part of its course its height was 30 or 40 miles. It thus traversed the upper regions of the air through 25° of longitude and 5° of latitude in a period of time not easily determined, but probably about two minutes. A part of the body may have passed on out of the atmosphere, but probably the remnants came somewhere to the ground in New York, or farther east.

A somewhat similar meteor was seen in the evening of July 20, 1860, by persons in New York, Pennsylvania, New England, &c., which first appeared over Michigan, at a height of about 90 miles. The light was so brilliant as to call thousands from their houses. It passed east-south-east, and over New York State, at a height of about 50 miles, broke into three parts which chased each other across the sky. At New York city it was seen in the north, while at New Haven it was in the south. At both places the apparent altitude was well observed, and its true height proved to be about 42 miles above the earth's surface between the two cities. It finally disappeared far out over the Atlantic Ocean. It is doubtful whether any one heard any sound of explosion that came from this meteor, and no part of it is known to have reached the ground. The velocity was at least 10 or 12 miles per second, or fifty times the velocity of sound. These two meteors were evidently of the same nature as those which have furnished so many stones for our museums, except that the one was so friable that it has given us but one known fragment, while the other was only seen to break in two, not even a sound of explosion being known to have come from the meteor.

Next to the stone-producing meteor is the fireball, or bolide, which gives generally a less brilliant light than the former, but in essential appearances is like it. The meteor of July 20, 1860, above described, though unusually brilliant, was one of this class, and represents thousands of bolides which have been seen to break in pieces. The bolides leave trains of light behind them just as the stone meteors do; they travel with similar velocities both apparent and actual, and in all respects exhibit only such differences of phenomena as would be fully explained by differences in size, cohesion, and chemical constitution of stones causing them.

Next to the bolide is a smaller meteor which appears as if one of the stars were to leave its place in the heavens, shoot across the sky, and disappear—all within the fraction of a second. Some meteors of this class are as bright as Venus or Jupiter. Some are so small that though you look directly at the meteor, you doubt whether you see one or

not. In the telescope still smaller ones are seen that are invisible to the naked eye. Meteors comparable in brightness to the planets and the fixed stars are usually called shooting stars.

These various kinds of meteors differ from all other luminous phenomena so as to stand in a group entirely alone. Though they have been sometimes regarded as separable among themselves into three or four different species, and for purposes of description may still be so divided, yet they all seem to have a like astronomical character, and the differences are only those of bigness, chemical constitution, velocity, &c. There appears to be no clear line of distinction between the stone-producing and the detonating meteors, nor between those heard to explode and those seen to break in pieces, nor between these and the simple fireballs, nor between the fireball and the faintest shooting star.

Altitudes of Meteors.—The first important fact about the meteors is the region in which they become visible to us. In hundreds of instances observations have been made upon the luminous path of a meteor at two or more stations many miles apart. When such stations and the path are properly situated relatively to each other, observations carefully made will show a parallax by which the height of the meteor above the earth, the length and direction of the path, and other like quantities may be computed. The general result from several hundred instances is that the region of meteor paths may be in general regarded as between 40 and 80 miles above the earth's surface. Some first appear above 80 miles, and some descend below 40 miles. But an altitude greater than 100 miles, or one below 25, except in the case of a stone-furnishing meteor, must be regarded as very doubtful. Thus the meteor paths are far above the usual meteorological phenomena, which (except auroras and twilight) have not one-tenth of the height of the meteors. But with reference to all other astronomical phenomena they are very close to us. The comets, for example, are well-nigh a millionfold, and even the moon is a thousandfold, more distant from us.

Velocities of Meteors.—When the length of a luminous path is known, and the time of describing it has been observed, it is easy to compute the velocity in miles. Unfortunately the large meteors, describing long paths, come at rare intervals, and unexpectedly, and it is a happy accident when one is observed by a person accustomed to estimate correctly short intervals of time. On the other hand, the total time of visibility of the shooting stars, which come so frequently that they may be watched for, is usually less than a second. It is not easy to estimate correctly such an interval, where the beginning and ending are not marked by something like a sharp click. Hence all estimates and computations of velocities of meteors are to be received with due regard to their uncertainty. We may only say in general that the velocities computed from good observations are rarely if ever under 8 or 10 miles a second, or over 40 or 50 miles, and that some have far greater velocities than others. The average velocity seems to be nearly 30 miles.

What makes the Luminous Meteor.—The cause of a meteor is now universally admitted to be something that enters the earth's atmosphere from without, with a velocity relative to the earth that is comparable with the earth's velocity in its orbit, which is 19 miles per second. By the resistance it meets in penetrating the air the light and other phenomena of the luminous train are produced. Under favourable circumstances, portions of these bodies reach the earth's surface as meteorites.

Meteoroids.—A body which is travelling in space, and which on coming into the air would under favourable circumstances become a meteor, may be called a meteoroid.

The meteoroids are all solid bodies. It would hardly be possible for a small quantity of gas out in space to retain such a density as would enable it on coming into the air to go 10 or 100 miles through even the rare upper atmosphere, and give us the clear line which a shooting star describes. Even if a liquid or gaseous mass can travel as such in space, it would be instantly scattered on striking the air, and would appear very unlike a shooting star or bolide.

Numbers of Meteors.—Of the larger meteors there are in the mean six or eight per annum which in the last fifty years have furnished stones for our collections. A much larger number have doubtless sent down stones which have never been found. Thus Daubrée estimates for the whole earth an annual number of six or seven hundred stone-falls.

But of the small meteors or shooting stars the number is very much larger. Any person who should in a clear moonless night watch carefully a portion of the heavens would, in the mean, see at least as many as eight or ten shooting stars per hour. A clear-sighted and practised observer will detect somewhat more than this number. Dr Schmidt of Athens, from observations made during seventeen years, obtained fourteen as the mean hourly number on a clear moonless night for one observer during the hour from midnight to 1 A.M. A large group of observers, as has been shown by trial, would see at least six times as many as a single person. By a proper consideration of the distribution of meteor paths over the sky, and in actual altitude in miles, so as to allow for mists near the horizon, it appears that the number over the whole globe is a little more than ten thousand times as many as can be seen in one place. This implies that there come into the air not less than twenty millions of bodies daily, each of which, under very favourable conditions of absence of sunlight, moonlight, clouds, and mists, would furnish a shooting star visible to the naked eye. Shooting stars invisible to the naked eye are often seen in the telescope. The numbers of meteors, if these are included, would be increased at least twentyfold.

How densely Space is filled with Meteoroids.—By assuming that the absolute velocity of the meteors in space is equal to that of comets moving in parabolic orbits (we have good reason to believe that this is nearly their true velocity), we may prove from the above numbers that the average number of meteoroids in the space that the earth traverses is, in each volume equal to that of the earth, about thirty thousand. In other words, there is in the average to every portion of space equal to a cube whose edge is about 210 miles one meteoroid large enough to make a shooting star bright enough to be visible to the naked eye. Such meteoroids would, upon an equable distribution, be each in round numbers 250 miles from its near neighbours. All these numbers rest upon Dr Schmidt's horary number fourteen, and for a less practised observer and a less clear sky they would be correspondingly changed. How much they would need to be altered to represent other parts of space than those near the earth's orbit is a subject of inference rather than of observation.

Motion in Space.—The meteoroids, whatever be their size, must by the law of gravitation have motions about the sun in the same way as the planets and comets, that is, in conic sections of which the sun is always at one focus. The apparent motions of the meteors across the sky imply that these motions of the meteoroids relative to the sun cannot as a rule be in or near the plane of the ecliptic. For if they were there, since the motion of the earth is also in the ecliptic, the motion of the meteoroids relative to the earth would be in the same plane. This would involve

that all the meteor paths as seen on the sky would if produced backward cross the ecliptic above the horizon. In fact there is no tendency of this kind. Hence the meteoroids do not move in orbits that are near the ecliptic as the planets do, but like the comets they may and usually do have orbits of considerable inclinations.

Numbers through the Night.—There are more meteors seen in the morning hours than in the evening. If the meteors had no motion of their own in space, the earth would by its motion receive the meteors only on the hemisphere that was in front. There would be no meteors seen in the other hemisphere. On the other hand, if the meteors had such large velocities of their own as that the earth's velocity might be neglected in comparison, and if the directions of the meteors' motions were towards all points indiscriminately, then as many would be seen in one part of the night as another. In fact there are about three times as many seen in the morning hours as in the evening. The law of change from evening to morning gives a means of proving that the mean velocity of meteors is so great that they must in general be moving in long orbits about the sun. In this respect also the meteoroids resemble comets, and are unlike planets, in their motions. Of the stone-furnishing meteors more are seen in the day than in the night, and more in the earlier hours of the night than in the later. This is probably due to the fact that more persons are in a position to see the stone-falls at the periods of greater abundance.

Star Showers.—While the average number of shooting stars for a single observer at midnight may be regarded as tolerably constant, there have been special epochs when many more have been seen. In certain instances the sky has been filled with the luminous trains, just as it is filled by descending snowflakes in a snowstorm, making a veritable shower of fire. One of the best-observed, though by no means the most brilliant, of these showers occurred on the evening of the 27th of November 1872. Some of the observers of that shower, counting singly, saw at the rate of eight or ten thousand shooting stars in the course of two hours. The distances of the meteoroids in the middle of the swarm which the earth then passed through, each from its nearer neighbours, would be 30 or 40 miles.

The following quotations show the impression made by star showers in times past :—

"In the year 286 [of the Hegira] there happened in Egypt an earthquake on Wednesday the 7th of Dhu-l-Ka'dah, lasting from the middle of the night until morning; and so-called flaming stars struck one against another violently while being borne eastward and westward, northward and southward, and no one could bear to look toward the heavens on account of this phenomenon."

"In the year 599 [of the Hegira], on the night of Saturday, on the last day of Muharram, stars shot hither and thither in the heavens, eastward and westward, and flew against one another like a scattering swarm of locusts, to the right and left; people were thrown into consternation, and cried to God the Most High with confused clamour."

"These meteors [November 12, 1799] might be compared to the blazing sheaves shot out from a firework."

"The phenomenon was grand and awful; the whole heavens appeared as if illuminated with sky rockets."

November 13, 1833. "Thick with streams of rolling fire; scarcely a space in the firmament that was not filled at every instant."

"Almost infinite number of meteors; they fell like flakes of snow."

November Meteors or Leonids.—These quotations all refer (except possibly the first) to a shower which has appeared in October and November of many different years since its first known occurrence on the 13th of October 902 A.D. Dates of these showers are given in the following table :—

Oct. 13, 902.	Oct. 17, 1101.	Oct. 28, 1602.	Nov. 13, 1833.
Oct. 15, 931.	Oct. 19, 1202.	Nov. 9, 1698.	Nov. 14, 1866.
Oct. 14, 934.	Oct. 23, 1366.	Nov. 12, 1799.	Nov. 14, 1867.
Oct. 15, 1002.	Oct. 25, 1533.	Nov. 13, 1832.	Nov. 14, 1868.

On several years after 1833, and before and after 1866–68, there were unusual numbers of those meteors seen on the mornings of November 13, 14, and 15, though perhaps they would have been unnoticed had there not been special watching for them. It will be seen that all these showers are at intervals of a third of a century, that they are at a fixed day of the year, and that the day has moved steadily and uniformly along the calendar at the rate of about a month in a thousand years. The change of twelve days in the 17th century is due to the change from old to new style.

The only explanation of this periodical display that is now seriously urged, and the one which is universally accepted by astronomers, is that there is a long thin stream of meteoroids, each of which is travelling about the sun in a conic section. These conic sections are all nearly parallel, and have nearly the same major axis, extending out about as far as to the orbit of Uranus, and each requiring the common period of thirty-three and a quarter years. The length of the stream is such that the most advanced members are six or eight years ahead of the hindermost, and they all cross the earth's orbit with a velocity of about 26 miles a second. Since the earth plunges through the group nearly in the opposite direction, the velocity with which they enter the air is 44 miles a second. One of the facts which have greatly aided us in arriving at this explanation is that these meteors in all the years and through all hours of the night cross the sky as we look at them in lines which diverge from a point near the centre of the sickle in the constellation Leo; hence the paths in the air are parallel. This implies that their velocities relative to the sun are all parallel and equal to each other. The radiation from Leo has given to them the name *Leonids*.

Orbit of the Leonids.—This orbit, common to all the Leonid meteors, is inclined to the ecliptic at an angle of 17° (or rather 163°, since the motion is retrograde), has a major axis of 10·34, a periodic time of 33·27 years, and a perihelion distance a little less than unity.

The above orbit, and that alone, explains the several appearances of the November meteors, the annual and the thirty-three year periods, the radiation from Leo, and the change of day of the month in the course of the centuries. This it does so completely that the result has never been questioned by astronomers. Shortly after the publication by Professor Adams in 1867 of the last link in the chain of the proof of this orbit, there was also published the definitive orbit of the comet 1866 I. That the comet was running almost exactly in the orbit of the meteors was at once recognized. In fact the comet is itself, in a sense, a meteoroid, and the principal member, so far as we know, of the group. Leonids had been seen in 1863, two years and two months in advance of the comet, while those of 1866 were ten months behind it. Those of later years (a few Leonids were seen even in 1870) were extended along the line of the comet's path behind it. The leaders of this long file of meteoroids had passed up beyond the orbit of Jupiter long before those which brought up the rear had crossed that planet's orbit going down toward the sun. The thickness of the stream is less than the ten-thousandth part of its length. In the densest part that we have recently passed through—namely, that traversed in 1833—the density of the stream may be expressed by saying that each meteoroid must in the mean have been 10 or 20 miles from its nearest neighbours.

What makes this Comet and these Meteors describe the same Orbit about the Sun?—Its path might have been inclined to the ecliptic at any angle instead of 163°. Or, with this inclination, its plane might have cut the earth's orbit at any other place than where the earth is on the 14th

of November. Or, happening to have these two elements in common, it might have passed the earth's orbit nearer the sun or farther away from it than the earth is. Or, having these three things in common, it might, by a slight difference in velocity, have had a periodic time much more or much less than thirty-three years. Or, with all these in common, it might have crossed the earth's orbit at a far different angle than the meteors. These several independent elements for the comet and the meteors are substantially identical, and this identity proves almost beyond doubt that between the two either there is now an actual or else there has been in the past a causal connexion. That there is now any physical connexion is thoroughly disproved by the immense magnitude of the stream, and by the isolation and distances from each other of the individual components. It seems difficult to find any cause that should bring into such a strangely shaped group bodies that had originally orbits distributed at random. Hence we are apparently forced to conclude that these meteoroids have something common in their past history. In fact they seem to have been once parts of a single body, and these common elements are essentially those of the parent mass. By some process not yet entirely explained they have become separated from the comet, thrown out of the control of its attractive power, and so left to travel each one in its own orbit. If the cause of separation was not too violent, each new orbit would necessarily be but slightly different from that of the comet. Very small variations in velocity, and hence in periodic time, would in the course of ages scatter the several individuals along the orbit even to the length of many hundreds of millions of miles.

The Meteor Group is not the Comet's Tail.—These meteoroids must be carefully distinguished from the comet's tails. The former follow or precede the comet exactly in the comet's path; the particles that compose the latter are driven off by the sun's repulsion directly away from the comet's path. The meteoroids and the comet have orbits with nearly common elements; the orbits of the particles of the tail have elements that are unlike each other, and unlike those of the comet. The meteoroids are undoubtedly solid masses; the tails are pulverulent or gaseous.

Twin Comets of 1366.—The comet 1866 I. is probably not the only one that has been connected with the November meteors. In 1366, a few days after the earth went through the meteor stream, a comet appeared in the northern heavens, and, passing directly in the line of the stream so close to the earth as to describe an arc of 90° in a single day, disappeared in the constellation Aquarius. Immediately upon its disappearance a second comet was seen in the north, which followed nearly in the same path. The Chinese accounts are not sufficiently exact to furnish independent orbits for them, but both comets were undoubtedly members of the Leonid stream. The comet 1866 I. may be identical with one of them.

The Andromeds and Biela's Comet.—Mention has been made of the star shower of November 27, 1872. The periodical comet known as Biela's, which makes three revolutions in twenty years, passes very near the earth's orbit at a longitude corresponding to November 27, but by reason of its direct motion the node has had considerable motion in longitude as the result of perturbations. Meteors having the same orbits as Biela's comet would have a radiant in the constellation Andromeda, that is, would cross the sky in lines diverging from a point in that constellation. They might, however, be at dates after or even before November 27.

Unusual numbers of meteors were seen December 7, 1798, by Brandes. A like abundance was seen December 7, 1838; and, as they had been expected, and radiation was now looked for, they were found to diverge from a point in Andromeda. Hence they have been called Andromeds. Since 1852 Biela's comet itself has been entirely lost. The star shower of November 27, 1872, previously referred to, had a radiant in Andromeda, and in every way appeared as though its meteors had once been parts of Biela's comet. A sprinkle three days earlier, on the night of November 24, had the same radiant, and came from a less dense outlying parallel stream. A small comet was seen in the southern sky by Pogson in the direction opposite to the radiant shortly after the shower. Biela's comet had been found in 1845-46 to be in two parts, which at its next return to perihelion in 1852 had separated to eight times their former distance. But the meteor streams of 1872 could hardly have been separated from the comet so recently, and the Pogson comet if of the same origin must also have left the parent mass at an earlier date than 1845. No ordinary perturbations would in a short period have so changed the orbits. The parts of the small stream traversed by the earth, December 1838 and December 1798, were far from the comet, and these fragments must have been thrown off much earlier.

The Perseids and the Comet 1862 III.—There is a third epoch when meteors appear in unusual numbers, viz., the 9th to 11th of August. This "sprinkle," as it may be called, has been seen constantly at the time named for nearly fifty years, and there are on record accounts of similar appearances in the earlier years before its annual character had been discovered. Some observers have thought that there were evidences of a variation having a long period, but the proof seems as yet unsatisfactory, and the display may be regarded as tolerably constant from year to year. On every 10th of August we may confidently expect a display of meteors that shall be at least four or five times as numerous as those of ordinary nights. The radiant is in the constellation Perseus, and hence the name Perseids.

The comet 1862 III., which has a period of more than a hundred years, passes close to the earth's orbit, nearly cutting it at the place of this shower, and has a velocity and direction corresponding to this radiant. Hence a connexion of the Perseid meteors with this comet is presumed, like that which the Leonids and Andromeds have with the comet 1866 I. and Biela. The meteors are distributed along this orbit more regularly than along either of the other two, and at the same time the breadth of this group is a hundred times greater than that of the Leonids. We must for the present regard it rather as a meteor ring, the meteoroids being scattered along the entire conic section which the comet describes. This ring has an inclination of 113° with the ecliptic.

Meteors of April 20-21—*Lyraids.*—About the 20th of April there have been several quite brilliant star showers, the earliest on record having been in the year 687 B.C. On that day meteors have been observed which radiated from Lyra, and to these the name Lyraids has been given. The comet 1861 I. passes near the earth's orbit in that longitude, and any meteors having such a connexion with it as is proved for the Leonids with comet 1866 I. would also radiate from Lyra.

Again, at several other periods of the year, meteors have been seen in unusual numbers which seem to be connected with certain comets.

Meteor Radiants.—We have thus definite proof that the earth at certain epochs plunges through meteor streams, and that these streams travel along the same track as certain comets. The question is at once asked—Do not the sporadic meteors, those which are seen on any and all nights of the year, belong to similar streams? An immense amount of labour has been spent in observing the paths of meteors, and classifying them, so as to detect and prove the existence of radiant points. As many as a thousand such radiants have been suggested by the different investigators. Some of these are duplicates, some will prove to be accidental coincidences; but a goodly number may reasonably be expected to endure the test of future observations. Such will show the existence of meteor streams, and perhaps will be connected with comets that are now known, or that may hereafter be discovered.

The radiants have been spoken of as if they were points in the heavens. This is so nearly true as to justify all the conclusions that have been deduced above. But in fact a radiant, even in the star showers in which it is most sharply defined, must be regarded as a small area. The apparent meteor paths when produced backward do not exactly meet in a point. If they be treated as proceeding from a small area, it does not appear that this is a long narrow one. Hence it may be shown that the paths of the meteors in the air are not exactly parallel either to a line or to a plane. This can hardly be due to a want of parallelism of the paths before the meteoroids meet the earth, but is rather due to their glancing as they strike the

air. These facts add not a little to the difficulties to be overcome by the energetic observers and investigators who are trying to deduce order out of an apparent chaos.

Meteorites.—The fragments which fall immediately after the disappearance of large meteors have been carefully collected and preserved in mineralogical museums, and have been studied with special interest. The largest collections in Europe are in Vienna, Paris, London, and Berlin, some of these representing over three hundred localities. In the United States there are large collections at New Haven, Amherst, and Louisville.

In several respects these fragments differ at first sight from terrestrial rocks.

They are when found almost always covered in part or entirely with a very thin black crust, generally less than $\frac{1}{50}$ of an inch in thickness. This crust may have a bright lustrous surface, or it may be of a lustreless black. It has evidently been melted, yet so rapidly as not to change in the least the parts of the stone immediately adjacent. Streaks showing the flow of the melted matter are often seen on the surface. Upon some surfaces are what appear to be deposits of the melted matter that has flowed off from the others. Some surfaces are only browned, showing an apparently recent fracture, and some cracks are found in stones which are not yet completely broken in two.

The surfaces very often have small cup-like cavities, sometimes several inches in diameter, sometimes like deep imprints in a plastic mass made by the ends of the fingers, and sometimes still smaller. These "cupules" have not only various sizes in different stones, but even in the same stone differ considerably from one surface to another. They appear in meteorites that are almost exclusively iron, as well as in those mainly destitute of that metal, and they may be regarded as a characteristic of meteorites.

The meteorites have usually metallic iron as one of their component parts. Native iron is very rare indeed among terrestrial minerals, and its presence in the meteorites is therefore characteristic. Sometimes the iron forms the principal part of the body, giving it the appearance of a mass of that metal. Sometimes it forms only a connected framework which is filled in with mineral matter. Sometimes particles of iron are scattered through a stony mass; and a few meteorites are said to be destitute of metallic iron altogether. The metallic iron is always accompanied with nickel.

The stony meteors when broken or cut through have usually a greyish interior, and often exhibit a peculiar globular structure. From the small rounded grains that give it this appearance, the name chondrite (from χόνδρος, a ball) has been applied to this kind of meteorite. Sometimes the irregular fragments are compacted into a kind of breccia.

The pieces as we find them are always apparent fragments of some larger mass, and there is no structural appearance which would indicate that the mass might not be a fragment of a still larger one. In some of the falls fragments picked up at a distance of miles from each other fit together in their simply browned surfaces, showing that they were true fragments recently separated. In some cases surfaces of the stones are partially polished. In some a cross section of the stone exhibits thin black lines as though the melted matter of the surface had been forced into the crevices of the partially broken stone.

The stones when seen to fall, if at once picked up, are usually too warm to be taken in the hand. But cases are on record in which the stones were excessively cold. They sometimes, on striking the ground, penetrate into it from 1 to 3 feet. In extreme cases large ones have struck much deeper into soft earth. Sometimes they are broken to pieces by the impact with the hard earth.

The stones are usually not very large. Although the light of the meteor is such as sometimes to be seen over a region 1000 miles in diameter, and the detonation gives phenomena suggestive of an earthquake over many counties, yet a stone exceeding 100 ℔ is quite exceptional in our collections. The total weight secured at any fall has rarely if ever amounted to a thousand pounds. The average weight of nine hundred and fifty perfect specimens of the Pultusk fall in the Paris museum is 67 grammes, or less than $2\frac{1}{2}$ oz. One of the Hessle meteorites in the Stockholm museum weighs less than 1 grain. Many of the Emmet county meteorites (May 10, 1879) are not much larger, though the largest specimen of that fall weighs nearly 500 ℔.

Meteors traversing the Atmosphere.—We can now get a very good idea of the history of that part of a meteorite's life between its entrance into the air and its arrival at the earth. It is entirely invisible until it has reached that height at which the density of the air is enough to create considerable resistance. Up to that time it moves almost exclusively in obedience to the sun's attraction. The earth's attraction may be neglected, especially during the passage through the air. Since the velocity is a hundred times that of sound, the elasticity of the air is impotent to remove it from in front of the meteorite, or to prevent a high degree of condensation. Perhaps the air is liquefied immediately in front of the stone. Heat is developed in it enormously, and the stone being pressed closely against the hot air is melted, with an intense light. The condensed air charged with the melted matter is pushed aside, and left behind nearly in the wake of the meteor to form the train. The brightness of the train rapidly diminishes behind the meteor, so that the light of the meteor and the train, modified by irradiation, make the whole appear to a distant eye of the shape of a pear or candle-flame. The stone being a poor conductor of heat, and itself rigid, is not heated in the interior either by condensation or conduction, and may reach the ground with its surface only heated, while the interior is as cold as it had been out in space.

If the stone is a small one it will soon be used up by this intense fire. Until its front surface is rounded by the flame, the irregular resistances may cause such a stone to glance. But if the stone is larger it will lose velocity less rapidly. As it comes down into the region where the air is more dense, it will in spite of loss of velocity meet greater resistance. The air pressed hard against it burns it unequally, forming cupules over its surface. The pressure of the air cracks the stone,—perhaps scaling off small fragments, perhaps breaking it into pieces of more uniform size. In the latter case the condensed air in front of the meteor being suddenly relieved will expand, giving the terrific explosion which accompanies such breaking up. In either case a fragment may have still velocity enough to burn on for an instant in its new path and then come invisibly to the earth, covered with a coating, the greater part obtained after the principal explosion. In the latter part of the course the original velocity has almost all disappeared, so that the sound travels faster than the meteor. The air's resistance exceeds the earth's attraction, and the stones strike the ground only with the force of a spent cannon ball. It is no doubt in violent disruption that some of the fractures are made in such a way as to give the rubbed and polished surfaces.

Trains of Meteors.—The smaller meteors generally have no perceptible train. Only in exceptional cases do the trains of ordinary shooting stars remain visible longer than a fraction of a second. An unusual number of the Leonids have a bluish train. But the brighter shooting stars and the larger meteors sometimes have trains that endure for minutes, and in extreme cases for an hour. Such trains are at first long narrow lines of light, though much shorter

than the track of the meteor. They begin at once to broaden in the middle and to fade away at one or both ends. Presently they become curved, sometimes with two or three convolutions. The white cloud floats slowly away among the stars, coiling up more and more, and finally fades out of sight. The cause of all this seems to be as follows. The heated air charged with the debris of the meteor is by the meteor's impact driven off horizontally, causing the narrow train to spread into a cloud. The currents of air differing in direction at different altitudes twist the cloud into its varied fantastic forms. Attempts to obtain the spectrum of the trains have been made, and sodium and magnesium lines have been thought to be detected in them. The observation, however, is one that is not easy to make or confirm. The trains have often colours other than white, and in the case of the brighter meteors different colours are seen in the different parts of the train.

Magnitude.—Some computations have been made of the size of the shooting star meteoroids from the mechanical equivalent of the light developed by their disintegration. If all the energy of the meteor is changed into light, then these computations would be conclusive. But a part is spent in disintegrating and burning the stone, a part in heating the air, and a part in giving direct motion to portions of air. A computation based on the light developed gives only a lower limit to the size.

It seems probable that the larger meteors might be safely regarded as weighing on entering the air only a few hundreds or at most a few thousands of pounds. The smallest visible shooting stars may be equal in size to coarse grains of sand, and still be large enough to furnish all the light exhibited by them. The largest shooting stars furnish matter enough to fill with thin trains cubic miles of space, but this need not require a very large mass.

Meteoric Irons.—There have been found at various times on the surface of the earth masses of metallic iron combined with nickel. These have been so like the irons which have been known to fall, both in their structure and in composition, that they have been without hesitation classed among the meteoric irons. A mass of this character weighing 1635 ℔, found in Texas, is in the Yale College Museum. The Charcas (Mexico) iron in the Paris museum is about the same size. A ring-shaped mass somewhat smaller, from Tuczon, is in the United States National Museum in Washington. A still larger mass is in the British Museum, and many other large masses are in public collections or private possession.

Widmannstätten Figures.—If in any of the meteoric irons, whether seen to fall or found on the earth, a section is cut and polished and then etched with acids, a series of peculiar lines are developed which are known as Widmannstätten figures. The lines of iron unattacked by the acid consist of an irregular grouping of parallel rulings often lying along the faces of a regular octahedron. The exhibition of these figures and the combination of iron with nickel have been usually considered conclusive evidence of the meteoric origin of any iron mass.

Nickel Iron of Ovifak.—In 1870 Baron Nordenskiöld, in his voyage to Greenland, found on the shore of the island of Disco fifteen iron masses, the largest of which weighed 20 tons, all in an area of half an acre. In the basaltic rocks not far distant other iron masses were found embedded in the basalt. The presence of nickel with the iron, and the development of lines like the Widmannstätten figures, were at once accepted as proof of their meteoric origin, in spite of the combination with basalt. A more complete examination has, however, established the terrestrial origin of these irons, and given reasons to hope for new discoveries of relations existing between the earth and the meteors. The additional discovery of small particles of metallic iron in certain other igneous rocks proves that the union of the Ovifak irons with basalt is not exceptional.

Chemical Constitution of the Meteorites.—No new element has been found in the meteorites. Three elements most widely distributed and most important among the meteorites—iron, silicon, and oxygen—are also most abundant in our earth. Daubrée gives the following lists of elements, arranged somewhat in the degree of their importance, in meteorites (Maskelyne adds lithium and antimony):—

Iron.	Titanium.	Arsenic.
Magnesium.	Tin.	Phosphorus.
Silicon.	Copper.	Nitrogen.
Oxygen.	Aluminium.	Sulphur.
Nickel.	Potassium.	Chlorine.
Cobalt.	Sodium.	Carbon.
Chromium.	Calcium.	Hydrogen.
Manganese.		

Minerals in Meteorites.—Among the minerals in the meteorites there are several which occur in the rocks on the earth. Among these are cited by Daubrée peridote, pyroxene, enstatite, triclinic felspar, chromite, magnetic pyrites, iron oxide, graphite, and probably water. Several minerals, however, are found which, so far as now known, are peculiar to the meteorites:—metallic nickel-iron, phosphide of iron and nickel (schreibersite), sesquisulphide of chromium and iron (daubréelite), sulphide of calcium (oldhamite), and chloride of iron (lawrencite).

Meteorites of different falls are in general unlike; but there are many instances in which the stones of two falls are so similarly constituted that it is not easy to distinguish them.

In four falls (Alais, Cold Bokkeweld, Kaba, and Orgeuil) the stones contain little or no iron. In these carbon appears not as graphite but in union with hydrogen and oxygen, and also with soluble and even deliquescent saline matters. The combinations are such as to suggest the existence of humus and organic remains. But after careful search nothing of this kind has been detected in them. In general the meteorites show no resemblance in their mechanical or mineralogical structure to the granitic and surface rocks on the earth. One condition was certainly necessary in their formation, viz., the absence of free oxygen and of enough water to oxidize the iron and other elements. Perhaps it is to this fact that are due the resemblances between these minerals and those of the deep-seated rocks of the earth in the formation of which free oxygen and water were also not present.

Gases in Meteorites.—The meteoric stones and irons when reduced to fine particles and placed in the vacuum of a Sprengel air-pump give off small quantities of gases which may be reasonably presumed to have been occluded by the irons at some time in their earlier history. Professor Graham found hydrogen in meteoric irons. Professor Wright has shown that a moderate heat drives off from the stony meteorites carbonic acid and carbonic oxide with a small amount of hydrogen. As the heat increases the proportion of hydrogen (and even some nitrogen) increases till at a full red heat the hydrogen given off is by far the largest portion. From the irons similar gases are given off, but the carbon compounds are not so large a component as hydrogen. The spectra seen in the tails of comets are not strikingly like those of any of these gases. But it is impossible to reproduce in the laboratory the conditions under which the matter of comet's tails is giving off its light. We cannot therefore say that these gases may not be the important parts of the cometic coma and tails.

Meteoroid as Part of a Comet.—Assuming that the meteorite and meteoroid once formed an integral part of a comet, not a little information is given us of the nature of this mysterious body. There is room also for speculation.

First, the comet may be a single hard body which comes from the cold of space into the heat of the sun, and there has fragments broken off, just as a stone is shattered in a hot fire. The nucleus of some of the comets must be very small because invisible in the telescope, and an impulse that would raise a stone on the earth only a few inches would send it permanently away from such a comet. The exposure of new surfaces to the heat of the sun might give occasion for the development of gas to form the comet's tail.

Or, secondly, the comet may be a tolerably compact aggregation of small bodies not in contact, each one being of the size of a meteoroid, and kept near to the rest, not by cohesion, but by their combined attraction. The total mass being small, some members of the group near the comet's perihelion passage can be by the sun's perturbing action thrown out into orbits quite independent of the comet itself, and yet such as relative to the sun shall resemble that of the main group. Perturbations resembling tidal waves might be preparing other members to be cast off at the next perihelion passage of the comet.

In either case, if we suppose, as seems probable, that the comet came from outside the solar system, and that a disturbance by a large planet changed the original hyperbolic orbit into an ellipse, the comet must have passed that planet as a very compact group, if not in a single mass, else the disturbance that changed the orbit would have scattered the group beyond the power of a future recognition of the common origin of the fragments.

Meteoroids as Fuel of the Sun.—The idea has been held by distinguished physicists that the meteoroids in falling into the sun furnish by their concussion a supply for the heat which the sun is constantly sending off into space,—that they are in fact the fuel of the sun. Such a view, however, receives but little support from facts which we know about meteors. The meteoroids of the August and two November periods are evidently permanent

members of the solar system moving in closed orbits. The same is by inference highly probable for most of the other meteoroids, and may be true of all of them. Permanent members of the solar system, however, if they ever fall into the sun, do so only after a long period of perturbation. If any meteoroids come from stellar spaces and have any uniform or random distribution of velocities or directions, only a very small portion of these would hit the sun's surface. The far greater portion would go on in hyperbolic orbits. But the earth receives the impact of its portion of these foreign meteoroids, both in their inward and outward course, and in addition encounters a full share of the permanent members of the solar system, of which the sun receives very few or none. It is not hard to show that a supply of meteoroids to the sun sufficient to make good its daily loss of heat would require that the twenty million meteoroids which the earth daily encounters, even if all were from stellar space, should have an average weight of hundreds of tons. The facts do not warrant the admission of any such magnitude even for the large meteors, much less for the ordinary and small shooting stars. Whatever be the source of the sun's heat, all the meteoroids of which we know anything are totally inadequate to supply the waste.

The literature of meteors and meteoroids is very much scattered. It is mainly contained in the scientific journals and in transactions of learned societies. The series of valuable *Reports* of the Luminous Meteor Committee of the British Association contains not only the record of an immense amount of original observations, but also year by year a digest of most of the important memoirs.

Meteoric science is a structure built stone by stone by many builders. In this article no attempt has been made to assign to each builder the credit for his contribution. (H. A. N.)

METEORA, a remarkable group of rock-built monasteries in Thessaly, in the northern side of the valley of the Peneus, not quite 20 miles north-east of Triccala, and in the immediate vicinity of the village of Kalabaka, Stagus, or Stagoi (the ancient Æginium). From the Cambunian chain two vast masses of rock are thrust southward into the plain, surmounted by a number of huge isolated columns from 85 to 300 feet high, "some like gigantic tusks, some like sugar-loaves, and some like vast stalagmites," but all consisting of iron-grey or reddish-brown conglomerate of gneiss, mica-slate, syenite, and greenstone. On the summit of these rocky pinnacles—accessible only by aid of rope and basket let down from the top, or in some cases by a series of almost perpendicular ladders climbing the cliff to the mouth of a tunnel—stand the monasteries of Meteora (τὰ Μετέωρα). At one time they were twenty-four in number; but Holland (1812) and Hughes (1814) found them reduced to ten; at Curzon's visit (1834) there were only seven; and in 1853 not more than four of these were inhabited by more than two or three monks. Meteora *par excellence* is the largest and perhaps the most ancient. The present building was erected, according to Leake's reading of the local inscription, in 1388 (Björnståhl, the Swedish traveller, had given 1371), and the church is one of the largest and handsomest in Greece. St Barlaam's and St Stephen's (the latter founded by the emperor John Cantacuzene) are next in importance. The decorations of the churches contain a large amount of material for the history of Byzantine art, not much inferior in value to the similar treasures at Athos.

Unless the identification with the Ithome of Homer be a sound one, there is no direct mention of the rocks of Meteora in ancient literature, and Professor Kriegk suggests that this may simply be due to the fact that they had not then taken on their present remarkable form. Æginium, however, is described by Livy as a strong place, and is frequently mentioned during the Roman wars; and Stagus appears from time to time in Byzantine writers.

See Holland, *Travels in the Ionian Isles, &c.*, 1815; Hughes, *Travels in Greece and Albania*, 1830; Curzon, *Visit to Monasteries in the Levant*, 1849; Leake, *Northern Greece*; Professor Kriegk in *Zeitschr. f. allg. Erdk.*, Berlin, 1858; Tozer, *Researches in the Highlands of Turkey*, 1869.

METEOROLOGY

METEOROLOGY, in its original and etymological sense, included within its scope all appearances of the sky, astronomical as well as atmospherical, but the term is now restricted to the description and explanation of the phenomena of the atmosphere which may be conveniently grouped under weather and climate. These phenomena relate to the action of the forces on which the variations of pressure, temperature, humidity, and electricity of the atmosphere depend, but in an especial sense to the aerial movements which necessarily result from these variations.

In the more exact development of meteorology, the scientific investigation of climate long preceded that of weather. Humboldt's work on *Isothermal Lines*, published in 1817, must be regarded as the first great contribution to meteorological science. The importance of this inquiry into the distribution of terrestrial temperature it is scarcely possible to overestimate, for, though the isothermals were necessarily to a considerable extent hypothetical, there cannot be a doubt that they presented a first sketch of the principal climates of the globe. Dove continued and extended the investigation, and in his great work *On the Distribution of Heat on the Surface of the Globe*, published in 1852, gave charts showing the mean temperature of the world for each month and for the year, together with charts of abnormal temperature. To this, more than to any other work, belongs the merit of having popularized the science of meteorology in the best sense, by enlisting in its service troops of observers in all parts of the civilized world.

In 1868 another series of important charts were published representing by isobaric lines the distribution of the mass of the earth's atmosphere, and by arrows the prevailing winds over the globe for the months and the year. By these charts the movements of the atmosphere and the immediate causes of these movements were for the first time approximately stated, and some knowledge was thereby attained of some of the more difficult problems of meteorology. It was shown that the prevailing winds are the simple result of the relative distribution of the mass of the earth's atmosphere, in other words, of the relative distribution of its pressure, the direction and force of the prevailing winds being simply the flow of the air from a region of higher towards a region of lower pressure, or from where there is a surplus to where there is a deficiency of air. It is on this broad and vital principle that meteorology rests, which is found to be of universal application throughout the science, in explanation, not only of prevailing winds, but of all winds, and of weather and weather changes generally. One of the more important uses of the principle is in its furnishing the key to the climates of the different regions of the earth; for climate is practically determined by the temperature and moisture of the air, and these in their turn are dependent on the prevailing winds, which are charged with the temperature and moisture of the regions they have traversed. The isobaric charts show further that the distribution of the mass of the earth's atmosphere depends on the geographical distribution of land and water in their relations to the sun's heat and to radiation towards the regions of space in different seasons.

In 1882 Loomis published a map showing the mean rainfall of the globe. This map and others that have been constructed for separate countries show conclusively that the rainfall of any region is determined by the prevailing winds considered in relation to regions from which they have come, and the physical configuration and temperature of the part of the earth's surface over which they blow. The maximum rainfall is precipitated by winds which,

having traversed a large breadth of ocean, come up against and blow over a mountainous ridge lying across their path, and the amount deposited is still further increased if the winds pass at the same time through regions the temperature of which constantly becomes colder. On the other hand, the rainfall is unusually small, or *nil*, when the prevailing winds have not previously traversed some extent of ocean, but have crossed a mountain ridge and advance at the same time into lower latitudes, or regions the temperature of which is markedly higher.

While the observational data for the determination of the geographical distribution of the prime elements of climate, viz., the pressure, temperature, moisture, and movements of the atmosphere and the rainfall were being slowly but surely collected, the great importance of the study of weather came gradually to be recognized. Additional impetus was given to this branch of study from its intimate bearings on the eminently practical question of storm warnings. Synchronous weather maps, showing the weather over a considerable portion of the earth's surface, were constructed, and some advance was made in tracing the progress of storms from day to day. Unquestionably one of the first problems of meteorology is to ascertain the course storms usually follow and the causes by which that course is determined, so as to deduce from the meteorological phenomena observed, not only the certain approach of a storm, but also the particular course that storm will take. The method of practically conducting this large inquiry in the most effective manner was devised by the genius of Leverrier, and begun to be carried out in 1858 by the daily publication of the *Bulletin International*, to which a weather map was added in September 1863. This map showed graphically for the morning of the day of publication the atmospheric pressure, and the direction and force of the wind, together with tables of temperature, rainfall, cloud, and sea disturbance from a large number of places in all parts of Europe. From such weather maps forecasts of storms are framed and suitable warnings issued; but above all a body of information in a very handy form is being collected, the careful study and discussion of which is slowly but gradually leading to the issue of more exact and satisfactory forecasts of weather, and to a juster knowledge of these great atmospheric movements which form the groundwork of the science.

The most cursory glance is sufficient to show that the ever-changing physical phenomena with which it is the business of meteorology to deal are all referable to the action of the sun, it being evident that if the sun were blotted out from the sky a cold lifeless uniformity would rapidly take possession of the whole surface of the globe. Meteorological phenomena naturally group themselves into two great classes,—those dependent on the revolution of the earth on its axis, and those dependent on its revolution round the sun taken in connexion with the inclination of its axis to the plane of its orbit. The science thus divides itself into two great divisions, the first comprising diurnal phenomena and the second annual phenome

Diurnal March of Phenomena.

Temperature.—Of the daily changes which take place in the atmosphere, the first place must be assigned to those which relate to temperature, seeing that on these all other changes are either directly or indirectly dependent. Observations of the temperature of the air are therefore of the first importance in meteorology. A perfectly accurate observation of the temperature of the air is unquestionably among the most difficult to make of all physical observations, the difficulty being to eliminate the effects of radiation of surrounding objects. The nearest approach yet made to the solution of this important problem of physical inquiry was made by Dr Joule in a communication to the Philosophical Society of Manchester (November 26, 1867, *Proc.*, vol. vii. p. 35). But the manipulative skill and time demanded by the method there detailed render it quite unsuitable for general adoption anywhere in collecting the observational data required in the determination of this important element of climate. It is therefore necessary to fall on some method which, while it gives results that can only be regarded as approximate, secures the essential element of uniformity among the observations.

Fig. 1 represents Stevenson's louvre-boarded box for the thermometers, which is now very widely used for temperature observations. The box is made of wood, and louvred all round so as to protect the thermometers inside from radiation, and at the same time secure as free a circulation of air as is consistent with a satisfactory protection from radiation. The box is painted white, both inside and outside, and screwed to four stout wooden posts, also painted white, firmly fixed in the ground. The posts are of such a length that when the thermometers are hung in position the bulbs of the minimum thermometer and hygrometer are exactly at the same height of 4 feet above the ground, the maximum thermometer being

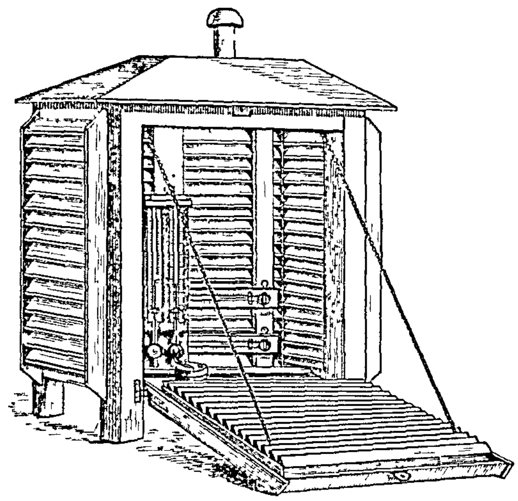

Fig. 1.—Thermometer Box.

hung immediately above the minimum thermometer. This thermometer box is placed over a plot of grass, and in a free open space to which the sun's rays have free access during as much of the day as surrounding conditions admit of. It will be observed that the thermometers are suspended on cross-laths in the centre of the box and face the door, which should always open to the north. It is not possible to overestimate the importance of seeing that uniformity of height above ground and method of protecting the thermometers is secured, since in no other way is it possible to obtain results from different places which shall be comparable with each other and thus supply satisfactory materials for the investigation and development of comparative climatology.

A desired uniformity is yet far from being attained among the meteorological systems of different countries. Thus in Russia the box for the protection of the thermometers is made of zinc, on the supposition that such a box follows more closely the changes of temperature of the air than a box of wood. Owing to these international diversities of observation, it is extremely desirable that steps were taken to ascertain, by Joule's method of observing, the approximate errors peculiar to each sort of thermometer box, in order that the temperatures of different countries may be compared together in a more satisfactory manner than has yet been possible.

Interchanges of temperature among bodies take place by conduction, convection, and radiation. In meteorology the most important illustrations of conduction are the propagation downwards through the earth's strata of the changes of the temperature of the surface as it is heated during the day and cooled during the night, and the propagation of the same changes of temperature through the lowest stratum of the air which rests on the surface. Since sand and light loose soils are much worse conductors of heat than clay and dense soils, it follows that loose soils

and tracts of sand are subject during the day to higher temperature and during the night to lower temperature near the surface than dense soils, and that frosts and extreme temperatures do not penetrate so far into loose as into dense soils. It is on these differences that some of the more striking features of climates depend. As snow is one of the worst conductors of heat, owing to the quantity of air filling the interstices among the ice crystals, it protects the soil it covers by setting a limit to the depth to which the severe frosts of the surface penetrate, and by arresting the escape of the heat of the soil upwards to the air.

The communication of heat from one part of the earth to another by convection is seen on a grand scale in the winds and in the currents of the ocean. It is seen also in the ascending and descending currents of the atmosphere everywhere, which have their origin in the daily and unequal changes of temperature to which the surface of the earth is subject. The direct and beneficial effect which results from atmospheric and oceanic circulation is a more equable distribution of temperature over the globe, thus moderating the rigours of the polar regions and the heat of the tropics.

An interchange of heat is constantly going on among bodies exposed to each other, whatever be their temperature. This mode by which heat is communicated from one body to another is called radiation. Radiant heat proceeds in straight lines, diverging in all directions from the source, is only in a limited degree influenced by the air through which it passes, and is not diverted from the straight course by the wind. The intensity is proportional to the temperature of the source, and is greater according to the degree of inclination of the surface on which the rays fall.

If then a body be placed in the presence of other bodies, some colder and some warmer than itself, it will from this mutual interchange of temperature receive more heat from the warmer bodies than it radiates to them, and consequently becomes warmer; but it will receive less heat from the colder bodies than it radiates to them, and its temperature consequently falls. This is precisely the condition in which the earth is placed in space. When a part of the surface is turned towards the sun, that part of the surface receives more heat than is radiated from it; and the temperature consequently rises most in that region which for the time is perpendicular to the sun's rays, and least round the annulus where the inclination of the surface is greatest. On the other hand, since the hemisphere turned from the sun radiates more heat than it receives from the cold regions of space, the temperature there falls. Owing to the essentially distinct conditions under which the earth is placed with respect to radiation, the subject falls naturally to be divided into two heads, solar radiation and terrestrial radiation.

Solar Radiation.—Of the sun's rays which arrive at the earth's surface, those which fall on the land and solid bodies generally are wholly absorbed by the thin surface layer exposed to the heating rays, the temperature of which consequently rises. Whilst the temperature of the surface increases, a wave of heat is propagated downwards through the soil. The intensity of the daily wave of temperature rapidly lessens with the depth at a rate depending on the conductivity of the soil, until at about 4 feet below the surface it ceases to be measurable. Part of the heat of the surface layer is conveyed upwards through the air by the convection currents which have their origin in the heating of the lowermost stratum of air in direct contact with the heated surface of the land.

Altogether different is the influence of the sun's rays on water. In this case the sun's heat is not all, indeed very far from all, arrested at the surface, but penetrates to a considerable depth. The depth to which the influence of the sun is felt has been shown by the observations made during the cruise of the "Challenger" to be, roughly speaking, about 500 feet below the surface of the sea. The rate at which, in perfectly clear water, this heat is distributed at different depths is a problem that has not yet been worked out. Since water is a bad conductor, the heat thus distributed does not, as takes place with respect to land, penetrate to still lower depths by conduction, but only by different densities prevailing at the same depths, whether these different densities be due to different temperatures or different degrees of salinity. Thus one of the more important distinctions between land and water surfaces in their bearings on climate is that nearly all the sun's heat falling on land is arrested on the surface, whereas on water it is at once diffused downwards to a great depth. In examining temperatures of the sea taken at different depths, it is surprising to note the rapidity with which changes of temperature are felt at considerable depths, especially in cases when the temperature of the air rises rapidly, accompanied with strong sunshine.

In shallow water the sun's heat raises the temperature much higher than that of deep water, this being obvious from the consideration that nearly the whole of the sun's heat which falls on the surface is utilized in raising the temperature of the shallow layer of water; in other words, it is, so to speak, concentrated through a small depth of water instead of being diffused through a great depth.

Surface Temperature of the Sea.—The importance of a knowledge of this datum of meteorology will be at once recognized when it is kept in view that three-fourths of the earth's surface is water, that the temperature of the air resting on this surface is in close relation to the temperature of the surface, and that the latter has, through the intervention of the winds, direct and important bearings on the temperature of the air over large portions of the land surfaces of the globe. During the years 1859–63 Captain Thomas, while engaged on the survey of the islands on the north-west of Scotland, made observations of the temperature of the surface of the sea every hour of the day at all seasons, and with sufficient frequency for the determination of the diurnal range of the temperature of the surface. The daily minimum, 0°·17 below the mean, occurred near 6 A.M.; the mean was reached about 11 A.M., the maximum, 0°·13 above the mean, between 3 and 4 P.M., and the mean again shortly before 2 A.M. Thus the daily oscillation of the temperature of the surface of the sea amounted on the north-west of Scotland only to 0°·3. In lower latitudes the amount of the daily fluctuation is somewhat larger, but everywhere it is comparatively small, if care be taken to make the observations properly, or at a distance from land, where the influence of the heated or cooled land is not allowed to vitiate the results.

During the voyage of the "Challenger" a complete system of meteorological observations, including the temperature of the surface of the sea, was made every two hours as part of the scientific work of the cruise. These are now being discussed, and the writer of this article is, by permission of the Lords Commissioners of H.M. Treasury, allowed to use such of the results as have been already arrived at.

The diurnal march of the temperature of the surface of the North Atlantic has been determined from observations made on one hundred and twenty-six days from March to August 1873 and in April and May 1876, the mean latitude of all the points of observation being nearly 30 N., and the longitude 42° W. The following variations from the mean show the phases of this diurnal oscillation:—

2 A.M.	−0°·24	10 A.M.	0°·06	6 P.M.	0°·26
4 ,,	−0·33	Noon	0·24	8 ,,	0·02
6 ,,	−0·29	2 P.M.	0·47	10 ,,	−0·19
8 ,,	−0·12	4 ,,	0·47	Midnight	−0·35

Thus in mid Atlantic, about 30° N. lat., where the sun's heat is strong, and at the time of the year when the sun is north of the equator, the diurnal fluctuation of the temperature of the surface is only 0°·80. It is highly probable that nowhere over the ocean does the mean daily fluctuation of the temperature of the surface quite amount to a degree. This small daily fluctuation is a prime factor in meteorology, particularly in discussions relating to atmospheric pressure and winds.

Temperature of Air over the Open Sea.—The following shows the daily march of the temperature of the air over the North Atlantic on a mean of the same one hundred and twenty-six days for which the temperature of the sea has been given:—

2 A.M.	−1°·13	10 A.M.	0°·78	6 P.M.	0°·73
4 ,,	−1·40	Noon	1·45	8 ,,	−0·30
6 ,,	−1·41	2 P.M.	1·80	10 ,,	−0·80
8 ,,	−0·21	4 ,,	1·56	Midnight	−1·02

The amplitude of the daily fluctuation of the air is thus 3°·21, or nearly four times greater than that of the sea over which it lies. During the same months the "Challenger" was lying near land on seventy-six days. The observations made on these days show a greater daily range of temperature of the air than occurred out in the open sea. The minimum, − 2°·05, occurred at 4 A.M., and the maximum, 2°·33, at noon, thus giving a daily range of 4°·38. The occurrence of the maximum so early as noon is doubtless occasioned by the greater strength of the sea breeze after this hour, this maintaining a lower temperature. Part of the increased range of the temperature of the air as compared with that of the sea was no doubt due to the higher temperature during the day and the lower during the night on the deck of the "Challenger" as compared with that of the air. But, after making allowance for this disturbing influence, it is certain that the temperature of the air has a considerably larger daily range than that of the sea on which it rests. The point is one of no small interest in atmospheric physics from the important bearings of the subject on the relations of the air and its aqueous vapour to solar and terrestrial radiation.

The hourly deviations from the mean daily temperature of the air at two places, one near the equator and the other in the north temperate zone, and both near the sea, viz., Batavia (6° 8′ S. lat., 106° 48′ E. long., mean temperature 78°·7) and Rothesay (55° 50′ N. lat., 5° 4′ W. long., mean temperature 47°·3), are these:—

Batavia.		Rothesay.	Batavia.		Rothesay.
1 A.M.	−3°·2	−1·7	1 P.M.	+5°·7	+2°·4
2 ,,	−3·6	−2·0	2 ,,	+5·6	+2·7
3 ,,	−4·0	−2·1	3 ,,	+5·2	+2·8
4 ,,	−4·3	−2·2	4 ,,	+4·3	+2·6
5 ,,	−4·7	−2·2	5 ,,	+3·3	+2·1
6 ,,	−4·9	−2·0	6 ,,	+1·9	+1·5
7 ,,	−4·3	−1·5	7 ,,	+0·6	+0·9
8 ,,	−2·2	−0·9	8 ,,	−0·4	+0·2
9 ,,	−0·5	−0·2	9 ,,	−1·2	−0·4
10 ,,	+2·8	+0·5	10 ,,	−1·8	−0·8
11 ,,	+4·4	+1·2	11 ,,	−2·3	−1·2
Noon	+5·4	+1·9	Midnight	−2·8	−1·5

The times of the four phases of the daily temperature at Batavia are—minimum about 5.50 A.M., mean 8.45 A.M., maximum 1.20 P.M., and mean 7.40 P.M.; while for Rothesay the same times are 4.30 A.M., 9.15 A.M., 3 P.M., and 8.20 P.M. At Batavia, where the days and nights are nearly equal during the year, there is little variation in these times through the months; but at Rothesay, where the days are much longer in summer than in winter, there is considerable variation in the times of occurrence of these phases. The following table shows the times of the phases for a number of selected places in the northern hemisphere for the two extreme months, January and July:—

	January.				July.			
	Min.	Mean.	Max.	Mean.	Min.	Mean.	Max.	Mean.
	A.M.	A.M.	P.M.	P.M.	A.M.	A.M.	P.M.	P.M.
Sitka	6.0	9.40	1.30	6.35	3.40	7.40	0.50	7.30
Toronto	6.20	10.0	1.50	9.40	3.50	8.15	3.45	8.10
Philadelphia	6.50	10.0	2.40	8.45	5.0	8.40	3.10	8.0
Havana								
Archangel	6.0	10.40	1.30	9.0	2.40	8.36	2.50	8.50
Rothesay	5.30	10.10	2.30	8.0	3.30	9.0	3.15	8.50
Oxford	7.20	10.10	2.0	7.0	3.40	8.45	3.10	8.25
Madrid	6.50	10.5	2.40	8.35	4.40	8.50	2.50	8.35
Geneva	6.0	10.0	2.0	8.0	3.15	8.15	2.50	8.10
St Bernard	4.30	8.25	0.55	6.45	3.0	8.10	1.20	7.50
Bogoslovsk	5.30	9.25	1.30	8.15	3.40	7.35	2.5	8.4
Petroalexandrovsk	6.50	9.50	2.35	7.45	4.30	8.20	2.40	8.25
Tiflis	7.10	9.50	2.25	7.50	5.0	9.5	3.10	8.15
Calcutta	6.30	9.35	2.30	8.20	5.30	8.45	0.40	7.30
Bombay	6.0	9.10	2.10	8.5	5.30	9.0	1.30	6.30
Madras	5.40	8.0	0.40	6.45	5.0	8.45	1.25	6.50

During the night in summer the temperature falls continuously from the effects of terrestrial radiation till the earliest dawn, when the daily rise in the temperature sets in owing to the heat reflected from the upper strata of the atmosphere, which have begun to be heated and lighted up by the rays of the morning sun. It will be observed that the time of the daily minimum temperature occurs earliest in high latitudes and latest in low latitudes. During winter, on the other hand, the minimum temperature takes place in several regions some time before dawn. At this season the two chief causes on which changes of temperature depend are the sun and the passage of cyclones and anticyclones; and it is probable that those cases where the minimum occurs markedly before the dawn are, where not occasioned by purely local disturbing causes, due to the mean diurnal times of occurrence of the changes of temperature which accompany the great atmospheric disturbances of cyclones and anticyclones.

In July the daily maximum temperature occurs generally from 2 to 4 P.M. At places, however, near the sea, which are within the immediate influence of the sea breeze, and in places at some distance from the sea, such as Calcutta, where the wind, being essentially a sea wind, attains its greatest daily velocity and the sky at the same time is much clouded, the maximum occurs nearly two hours earlier. In high situations, such as the St Bernard hospice, the highest daily temperature also occurs nearly two hours sooner than on the plains below. In the winter months the maximum is about an hour earlier than in the summer.

In investigating the daily curves of temperature, Sir David Brewster drew several interesting conclusions from them. By dividing the daily curve of temperature, deduced from the mean of the year, into four portions, at the points representing the two daily means and the two extremes, he showed that the four portions approximate to parabolas, in which the temperatures are the abscissæ and the hours the ordinates. The correspondence between the observed and calculated results is so close that the difference did not in any case exceed a quarter of a degree Fahrenheit. This interesting result is true for places at which the horizon is open all round, so that no shadows of hills, trees, or buildings fall on the places where the thermometers are kept during the day. If a hill rises to the

north of the place, by which the sun's rays are never obstructed, it exercises little, if any, influence on the observations; but if one or more hills obstruct the rays of the sun after it has risen above the horizon, such obstruction affects the temperature while, and for some time after, the position in which the thermometer is placed is shaded from the sun.

Brewster further made the important remark that the mean of observations made at any pair of hours of the same name, such as 8 A.M. and 8 P.M., 9 A.M. and 9 P.M., &c., does not differ much from the mean temperature of the day. The pairs of hours which approximate closest to the true daily mean are 9 A.M. and 9 P.M., 10 A.M. and 10 P.M., 3 A.M. and 3 P.M., and 4 A.M. and 4 P.M. The mean of four hours at equal intervals from each other gives a result still closer to the true mean temperature.

In organizing any system of meteorological observation, by which it is intended to develop the climatology of the country, the determination of the hours of observation is a question of the first importance. If only two observations be made daily the best hours are 9 A.M. and 9 P.M., or 10 A.M. and 10 P.M.; and if there be four observations the best hours are 3 and 9 A.M. and 3 and 9 P.M., or 4 and 10 A.M. and 4 and 10 P.M. If there be three observations the best hours are 9 A.M. and 3 and 9 P.M., or 10 A.M. and 4 and 10 P.M.; but in these cases it is essential that the observations of a minimum thermometer be added to the temperature observations. These hours are further strongly recommended by the consideration that they are approximately coincident with the diurnal phases of atmospheric pressure, an exact knowledge of which lies at the root of nearly all climatological inquiries. The three equidistant hours which have been adopted in several countries, viz., 6 A.M. and 2 and 10 P.M., are only good as regards the temperature, not as regards atmospheric pressure. With respect to two daily observations, the hours 8 A.M. and 1 P.M., which have been adopted in some countries, are singularly unsuitable for the furnishing of the observational data required in the development of the climatologies of these countries; and, what is still more serious in a science where international co-operation is so imperatively demanded, these observations cannot be used with any satisfaction in such deeply important inquiries as the comparative climatologies of Europe.

The times of occurrence of the highest, lowest, and mean daily temperatures, and the amount of the daily range of temperature, are in a great degree influenced by the covering or want of covering of the earth's surface on which the air rests. When the ground is covered with vegetation, the whole of the solar heat falls on the vegetable covering; and, as none falls immediately on the soil, its temperature does not rise so high as happens where there is no vegetable covering to shade the surface from the sun. The temperature of plants exposed to the sun is not so high as that of exposed soil in the vicinity. As regards forests, the four diurnal phases of temperature occur later than in the open country, and the maximum and minimum are less decided; and, since the maximum temperature of the air in forests falls short of the maximum in the open to a considerably greater extent than the minimum under trees is above the minimum in the open, it follows that the mean temperature of the air in forests is less than that of the open country adjoining. The reason of the difference is that the chilling effects of nocturnal radiation penetrate lower down among the trees than do the heating effects of solar radiation; and as the soil is not heated directly by the sun its temperature is lower, and consequently that of the air over it is also lower. A cleared space in a forest, sheltered by the surrounding trees, but open to the sun, has a warmer and moister atmosphere in spring and summer and very much moister in autumn than prevails in the open country adjoining, and has also the diurnal differences of range peculiar to a warmer and moister atmosphere.

One of the most important elements of climate is disclosed by the difference between the hour of lowest and the hour of highest mean temperature respectively, or, as it is usually expressed, by the daily range of temperature. We have seen that as regards the sea in the north-west of Scotland the difference is only 0°·3 and in the Atlantic about 30° N. lat. 0°·8, and that probably the diurnal range of temperature of the surface of the sea nowhere amounts to a degree. In the same part of the Atlantic the daily range of the temperature of the air resting on the ocean is 3°·2, and on the sea near land 4°·4. On advancing on the land, the daily range of temperature rapidly increases, and the rate of increase is greatly augmented when an inland position is arrived at to which any sea breezes that may prevail do not extend.

The true daily range of temperature is stated by observations made with maximum and minimum thermometers. Generally speaking, the amount of the range increases as the latitude is diminished, and as the distance from the sea is increased, but above all it increases in proportion to the dryness of the climate.

The differences of this vital element of climate are strikingly shown in the meteorology of India. In the *Report* for 1880 the following are the mean daily ranges of March of that year at a few places: at Goa 5°·4, Bombay 11°·2, Kurrachee 23°·5, Jacobabad 37°·4, and Pachbudra (lat. 25° 55′ N., long. 72° 18′ E.) 41°·3. In the last case, undoubtedly one of the greatest mean daily ranges of temperature meteorology has yet recorded, the mean of the days was 103°·4 and of the nights 62°·1. As March is altogether within the season of the north-east monsoon, the general drift of the wind over western India, where these are situated, is from the interior towards the sea, subject as regards Bombay and Goa to the influences of the land and the sea breeze. On the other hand, in June, when the south-west monsoon has fairly set in, the following are the mean daily ranges of temperature at the same places: at Goa 5°·6, Bombay 8°·2, Kurrachee 16°, Jacobabad 27°·6, and Pachbudra 24°·1. These show in a striking manner the powerful influence of the moister atmosphere spread over India by the south-west monsoon, under which the daily range of temperature falls at Kurrachee from 23°·5 to 16°, and in the excessively arid climate of Pachbudra from 41°·3 to 24°·1. In these dry climates of the basin of the Indus, whilst the rainfall both in March and in June is practically nil, yet the relative humidity of the atmosphere is widely different. Thus the humidities for March and June respectively at 4 P.M., when the temperature is nearly the maximum for the day, are 48 and 77 for Kurrachee, 18 and 30 for Jacobabad, and 11 and 36 for Pachbudra. It is not so much the amount of cloud that determines the degree of fierceness of the sun's heat in these climates as the relative humidity, or the dryness of the air, as pointed out by Strachey in 1866. Thus at Jacobabad less than half the amount of cloud appears in the sky in June as compared with March, but the relative humidities are 30 and 18, and the daily range of temperature 27°·6 and 37°·4. If we except the dry arid wastes of Persia and Arabia, there is perhaps no other region of the globe where the daily range of temperature approaches that of the valley of the Indus. Thus in the dry climates of such places as Sacramento (California) in summer it amounts only to about 30°, at Madrid to 27°, and Jerusalem 24°. In central districts in the south of England it is about 20°; farther north it falls to 15°; and in the islands in the north, whose climate is strictly insular in its character, the summer daily range is only 10°. In Arctic regions, such as Spitzbergen and Boothia Felix, the range in winter varies from 0°·0 to 1°·0; in May, when the sun has reappeared and continues to rise and set, it rises to 14°; but in July, when the sun does not set, the range sinks to 10°.

But maximum and minimum thermometers not only show the mean daily range of temperature, they are also of great utility in giving observations for the determination of mean temperature. The mean temperature may be accepted as the mean of the twenty-four hourly observations of the day. If with such a system of observation daily readings of the maximum and minimum thermometer be compared, the value of the latter observations in questions of mean temperature may be arrived at. Double series of observations of this description have been made at many places. The following shows a comparison of the mean of maximum and minimum daily temperatures with means from observations made twenty-four times daily, the former exceeding the latter means in nearly all cases:—

	Spring.	Summer.	Autumn.	Winter.	Year.
Batavia	−0·3	−0·2	−0·2	−0·2	−0·2
Calcutta	1·0	0·7	0·7	0·9	0·8
Peking	0·6	0·6	0·6	0·7	0·6
Nertchinsk	0·1	0·3	0·6	1·0	0·5
Barnaul	0·5	0·5	0·7	0·8	0·6
Ekaterinburg	0·5	0·7	0·7	0·6	0·6
Tiflis	0·5	0·5	0·5	0·4	0·5
St Petersburg	0·6	0·6	0·3	0·1	0·4
Valentia	0·4	0·5	0·1	−0·1	0·2
Greenwich	0·7	0·8	0·6	0·0	0·4
Rothesay	0·4	0·3	0·3	0·3	0·3

These results show remarkable uniformity, and it may be inferred from them that mean temperatures deduced from maximum and minimum observations are about half a degree above the true mean temperature. In general climatological inquiries, observations with these thermometers have the strong recommendation of supplying from observations taken once a day the data for the determination of the mean temperature and mean daily range of localities; to which falls to be added the further advantage of giving results more uniformly comparable for different places than could be afforded by observations made with a common thermometer at any single hour or pair of hours daily.

Daily Variation of the Humidity of the Air.—The gaseous envelope surrounding the earth is composed of two atmospheres, quite distinct from each other,—an atmosphere of dry air and an atmosphere of aqueous vapour. The dry air, which consists of oxygen and nitrogen, is always a gas, and its quantity remains constant; but the aqueous vapour does not continue permanently in the gaseous state, and the quantity present in the air is, by the ceaseless processes of evaporation and condensation, constantly changing. If the aqueous vapour remained permanently and unchanged in the atmosphere, or were not liable to be condensed into cloud or rain, the mixture would become as complete as that of the oxygen and nitrogen of the air. The equilibrium of the vapour atmosphere, however, is being constantly disturbed by every change of temperature, by every instance of condensation, and by the unceasing process of evaporation. Since dry air further materially obstructs the free diffusion of the aqueous vapour, it follows that the law of the independent pressure of the vapour and of the dry air of the atmosphere holds good only approximately. The aqueous vapour, however, constantly tends to approach this state. Since, then, the independent and equal diffusion of the dry air and the aqueous vapour is, owing to these disturbing causes, never reached, the important conclusion follows that the hygrometer can never indicate more than the local humidity of the place where it is observed. Hygrometric observations can therefore be regarded only as approximations to a true indication of the quantity of aqueous vapour in the atmosphere over the place of observation. It is, however, to be added that, while in certain cases the amount of vapour indicated is far from the truth, yet in averages, particularly long averages, a close approximation to the real amount is reached if the hygrometer be at all tolerably well exposed and carefully observed.

Aqueous vapour is constantly being added to the air from the surfaces of water, snow, and ice, from moist surfaces, and from plants. The rate of evaporation increases with an increase of temperature, because the capacity of the air for vapour is thereby increased. The atmosphere can contain only a certain definite amount of vapour, according to the temperature; when therefore the air has its full complement of vapour, or when, in other words, it is saturated, evaporation ceases. Thus the rate of evaporation is greatest when the air is driest or freest from vapour, and least when the air is nearest the point of saturation. Since currents of air remove the moister and substitute drier air over the evaporating surfaces, evaporation is much more rapid during wind than in calm weather. As air expands under a diminished pressure, its temperature consequently falls, and it continues to approach nearer to the point of saturation, or become moister; and, as it contracts under an increased pressure, its temperature rises and it recedes from the point of saturation or becomes drier. Hence ascending currents of air become moister with every addition to the ascent, and descending currents drier as they continue to descend. Thus as winds ascend the slopes of hills they become moister, but when they have crossed the summit and flow down the other side they become drier in proportion to the descent, and all the changes may be experienced from extreme dryness to saturation in the same mass of air, which all the time has practically had its amount of aqueous vapour neither added to nor diminished.

In an atmosphere of air and aqueous vapour perfectly mixed, the elastic force of each at the surface of the earth is the pressure of each. In this case the elastic force of aqueous vapour would be the pressure of the whole vapour in the atmosphere over the place of observation. This pressure is expressed in inches of mercury of the barometer. If we suppose the total barometric pressure to be 30·000 inches, and the elastic force of vapour to be 0·745 inch, the pressure or weight of the dry air, or air proper, would be 29·255 inches, and of the aqueous vapour 0·745 inch. From this it follows that the elastic force of vapour may be regarded as indicating the quantity of aqueous vapour in the air at the place of observation, or it may be designated the absolute humidity of the air.

The diurnal variation in the elastic force of vapour in the air is seen in its simplest form on the open sea. Grouping together all the hygrometric observations made on board the "Challenger" on the North Atlantic at a distance from land, from March to July 1873 (eighty-four days), we have for that time a mean elastic force of 0·659 inch, and the following diurnal variation:—

	Inch.		Inch.		Inch.
2 A.M.	−·015	10 A.M.	+·004	6 P.M.	+·007
4 ,,	−·020	Noon	+·017	8 ,,	+·002
6 ,,	−·016	2 P.M.	+·020	10 ,,	−·005
8 ,,	−·007	4 ,,	+·017	Midnight	+·003

Hence the minimum (−·020 inch) occurs at the hour when the temperature of the surface of the sea and air resting over it falls to the daily minimum; it then rises to the mean a little after 9 A.M., and to the daily maximum (+·020 inch) at 2 P.M., when the sea and air are also near the daily maximum, and falls to the mean shortly before 9 P.M.

Treating the observations made near land by the "Challenger" during the same months, the following is the diurnal variation disclosed:—

	Inch.		Inch.		Inch.
2 A.M.	−·003	10 A.M.	+·014	6 P.M.	·000
4 ,,	−·009	Noon	+·011	8 ,,	−·004
6 ,,	−·010	2 P.M.	+·007	10 ,,	−·005
8 ,,	−·003	4 ,,	+·015	Midnight	−·007

The disturbance induced by proximity to land in the distribution of the aqueous vapour in the lower strata of the atmosphere is very striking. The maximum and minimum no longer follow the corresponding phases of the temperature of the surface of the sea and of the air. The disturbing agents are the sea and land breezes and their effects. Under the influence of the land breeze the time of the minimum humidity is delayed till about 6 A.M.; and under the influence of the sea breeze and its effects the amount of the aqueous vapour shows a secondary minimum from noon to 2 P.M. It is to be here noted that this midday

minimum occurs at the hours of the day when the surface of the land is most highly heated, the ascending current of heated air rising from it therefore strongest, and the resulting breeze from the sea towards the land also strongest. Now it does not admit of a doubt that the diminution in the amount of the aqueous vapour noted on board the "Challenger" near the shore points to an intermixture with the air forming the sea breeze of descending thin air-filaments or currents to supply the place of the masses of air removed by the ascending currents which rise from the heated surface of the land. At Batavia, on the north coast of Java, and at Bombay, the aqueous vapour is also subject to a secondary minimum during the warmest hours of the day.

During the summer months this secondary minimum is best marked at inland places such as Peking, Nertchinsk, Barnaul, Tiflis, and Ekaterinburg, but the time of its occurrence is about two hours later than it is over the North Atlantic. Over all these places at this season the ascending current from the heated land in the interior of Asia is very strong. On the other hand the lowering of the amount of aqueous vapour scarcely if at all appears as a feature in the summer climate of St Petersburg, and not at all in that of Sitka, where the sea breeze is equally not a constant feature of the climate of the district.

In the excessively dry, rainless, and hot climate of Allahabad, in April the diurnal minimum of the aqueous vapour occurs from 11 A.M. to 6 P.M., the time of absolute minimum being 2 and 3 P.M. During all other hours of the day the amount of the vapour is above the mean, a secondary minimum occurring from 1 to 4 A.M. At Allahabad, at this time, the absolute maximum vapour pressure occurs at 8 A.M. Quite similar to this is the diurnal distribution of the aqueous vapour in July at Lisbon and Coimbra, the minimum occurring from 10 A.M. to 8 P.M. At this time of the year the climate of this part of the peninsula is hot and dry and the rainfall insignificant in amount. As this region lies between the high atmospheric pressure so characteristic a feature of the meteorology of the Atlantic in summer and the comparatively low pressure over the continents southward and eastward, the winds are almost wholly north-westerly. In this connexion it is instructive to note that the time of maximum vapour pressure is from 4 to 7 A.M., when the velocity of the wind is near the minimum, and the chief minimum vapour pressure from noon to 4 P.M., when the velocity of the wind and ascending currents reach the daily maximum. These results show that the diminution in the vapour pressure during the hours when temperature is highest, which characterizes the climates of large tracts of the globe, is due to descending air-filaments or currents, which necessarily accompany the ascending currents that rise from the heated land.

At Geneva during the summer months the vapour curve exhibits two daily minima very strongly marked, the one shortly before sunrise and the other from 2 to 4 P.M., and two maxima, one from 8 to 11 A.M. and the other from 6 to 10 P.M.; and with these the diurnal variations of cloud are in accordance. The peculiarly marked features of the vapour curve at Geneva are probably due to the size of the lake, which is large enough to give rise to a decided breeze during the day from the lake all round its shores and during the night to a breeze from the land all round upon the lake. On the setting in of the breeze, the mass of air composing it, having been for some time resting on the lake, is rather moist, and thus one of the daily maxima is brought about from 8 to 11 A.M. As the breeze continues the air supplying it is necessarily drawn from the higher strata of the atmosphere more copiously than in different situations; and, having thus acquired increased dryness in the descent, and having blown over the lake for too short a distance to materially influence its moisture, the air becomes constantly drier, till the minimum from 2 to 4 P.M. is reached. The lake breeze thereafter begins to diminish in force, and the air consequently becomes moister till the maximum vapour pressure of the day occurs when the lake breeze dies away and the land breeze has not yet sprung up. In the winter months, when these breezes do not prevail, the curve of diurnal vapour pressure shows only one maximum and minimum.

The *relative humidity* of the atmosphere must not be confounded with its vapour pressure or absolute humidity. The relative humidity, or, as it is more frequently called, the humidity, of the air is the degree of its approach to saturation. Complete saturation is represented by 100 and air absolutely free of vapour by 0, the latter state of things never occurring in the atmosphere, a humidity of 10 being of rare occurrence even in such arid regions as those of Arabia. The great significance of this element of climate is in its relations to the diathermancy of the air, and consequently to solar and terrestrial radiation. It is supposed that perfectly dry air would allow rays of heat to pass through it with at most only a very slight increase to its temperature therefrom. Let, however, a little aqueous vapour be added to it, a partial obstruction to the passage of radiant heat is offered, and the temperature of the mixture, or common air, is sensibly raised. Hence, other things being equal, the less the amount of vapour the more are the effects of radiation felt, or the greater the heat of the days and the cold of the nights. The mere amount of vapour in the air does not determine the degree of radiation, but it is the amount of vapour together with a certain temperature—in other words, the absolute and relative humidity of the air taken together—that determines the heating power of the sun and the degree of cold produced by terrestrial radiation.

The diurnal variation of the relative humidity is very different from that of the vapour pressure, and presents features of the simplest character. The following are the diurnal variations from the mean humidity 80 over the North Atlantic, from the "Challenger" observations in 1873:—

2 A.M.	+2	10 A.M.	−1	6 P.M.	−1
4 ,,	+2	Noon	−2	8 ,,	0
6 ,,	+1	2 P.M.	−3	10 ,,	+1
8 ,,	0	4 ,,	−2	Midnight	+2

Thus the maximum humidity occurs from midnight to 4 A.M., or when the daily temperature is at the minimum, and the minimum humidity at 2 P.M., when the temperature is at the maximum, the curve of humidity being thus inverse to that of the temperature. With two slight modifications this is the diurnal humidity curve for all climates and seasons. In the calm which intervenes in the morning between the land and the sea breeze the humidity continues high, or even increases, though at the time the diurnal increase of temperature has already set in. The other modification is seen in the humidity curves for Nertchinsk and Barnaul during winter, these curves being not inverse but coincident with the daily curves of temperature. In the climates of Central Asia in winter, the amount of vapour is very small, and the increase to the relative humidity during the day is probably occasioned by the more active evaporation from the snow during the day and the stillness of the air favouring the accumulation of aqueous vapour near the surface of the earth.

Next to the winds, the aqueous vapour of the atmosphere, in the diverse ways in which in different localities it is distributed through the hours of the day, plays the most important part in giving to the different parts of the globe its infinitely diversified climates.

Dew.—Dew is deposited over the earth's surface on comparatively clear and calm nights. As the cooling by terrestrial radiation continues, the temperature of objects on the surface is gradually lowered to the dew-point, and when this point is reached the aqueous vapour begins to be condensed into dew on their surfaces. The quantity deposited is in proportion to the degree of cold produced and the quantity of vapour in the air. Dew is not deposited in cloudy weather, because clouds obstruct the escape of heat by radiation, nor in windy weather, because wind continually renews the air in contact with the surface, thus preventing the temperature from falling sufficiently low. When the temperature is below 32°, dew freezes as it is deposited, and *hoar-frost* is produced. The dew-point practically determines the minimum temperature

of the night,—because if the temperature falls a little below the dew-point the liberation of heat as the vapour is condensed into dew speedily raises it, and if it rises higher the loss of heat by radiation speedily lowers it. This consideration suggests an important practical use of the hygrometer, it being evident that by ascertaining the dew-point the approach of frost or low temperature likely to injure vegetation may be foreseen and provided against.

Diurnal Oscillations of the Barometer.—The general character of the daily oscillations of atmospheric pressure is shown by the two curves of fig. 2. The solid line gives the mean oscillation for Bombay and the

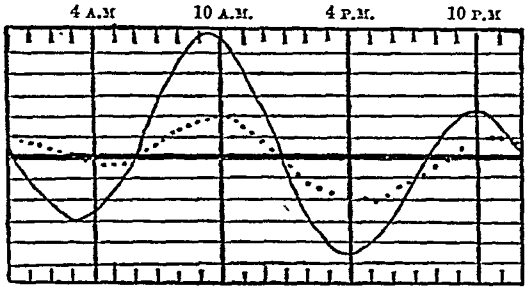

FIG. 2.—Daily Oscillations of Atmospheric Pressure.

dotted line that for Vienna, these two curves being to a large extent typical of diurnal barometric oscillations in tropical and temperate regions as regards the two maxima and minima and the time of their occurrence.

A series of twelve maps of the globe were prepared for June, showing, for all stations whence observations have been obtained, the deviations at noon, 2 P.M., 4 P.M., &c., Greenwich mean time, from the mean daily pressure; and four lines were drawn indicating the positions of the two daily maxima and minima at these hours. For fully 30° north and south of the equator the lines of maxima and minima run north and south, but in higher latitudes these directions are changed, and the changes are chiefly conspicuous as regards the A.M. maximum and the P.M. minimum. Thus, for example, at 6 P.M. (G. M. T.) the line of P.M. minimum is for the latitude of London near 16° W. long.; in 30° N. lat. it is in 35° W. long., in which the line runs south as far as 30° S. lat.; its course thence turns south-westwards to near the Falkland Islands, 60° W. long. Hence in June the P.M. minimum occurs about three hours earlier in the Falkland Islands than to the south-west of Ireland, thus showing in a striking manner the influence of season on this phenomenon. In the middle and higher latitudes in summer, proximity to the sea delays the time of occurrence of the A.M. maximum and the P.M. minimum; whilst in continental situations the A.M. maximum occurs much earlier than in lower latitudes, and the P.M. minimum nearly as late as at places near the sea. In cases where the lines of maxima and minima cross a region such as southern and western Europe, whose surface is diversified by large tracts of land and sheets of water, the deflexions are of a remarkable character.

The retardation of the time of occurrence of the A.M. maximum is greatest in situations which, while eminently insular in character, are at the same time not far from an extensive tract of land. Of this Holland presents the best example in Europe; and there the A.M. maximum, which at Paris occurs at 8 A.M., does not occur at Utrecht till 9.30 A.M., at Amsterdam till 12.30 P.M., and at Helder till 2 P.M. There is thus as regards the same diurnal phenomenon in June a difference of six hours between Paris and Helder. Sicily and the south of Italy on the one hand and Madrid on the other present also the most striking contrasts. Again at Sitka (56° 50′ N. lat., 135° W. long.), which has one of the most truly insular climates in the world, the A.M. maximum is delayed to 2.30 P.M.; whereas at Astoria, ten degrees to southward, it occurs at 9.30 A.M., and at Fort Churchill, in Nevada, as early as 7 A.M. There is thus as regards the same phenomenon a difference of $7^h\ 30^m$ between Sitka and Fort Churchill.

From hourly observations made in this month at the base, the top, and two intermediate points on Mount Washington (N. H.) it was found that the time of occurrence of the A.M. maximum at the base of the mountain, which is 2898 feet above the sea, was 8 A.M.; at 4059 feet, 10 A.M.; at 5533 feet, 11 A.M.; and at the top, 6285 feet, noon. Hence, as regards the time of occurrence, the influence of an isolated mountain like Mount Washington brings about a result similar to what is observed in insular situations. But the analogy is even closer. In insular climates the minimum in the early morning is very greatly in excess of that in the afternoon; and the same relation is observed on the top of Mount Washington, where the former is −0·020 inch and the latter −0·004 inch. Again in continental climates the minimum in the early morning is much the smaller of the two, and the same relation was observed at the base of the mountain, where the observed minima were respectively 0·006 inch and 0·020 inch. The differences presented by the daily curve of pressure at the top as compared with that at the base of the mountain have their explanation in the effects which follow the diurnal range of temperature. As the temperature is at the minimum at the time of least pressure in the morning, the atmosphere is more condensed in the stratum between the base and the top, and consequently the barometer at the top reads relatively lower. As the temperature continues to rise during the day, the stratum of air above the base of the mountain expands, thus placing more air above the barometer at the top, so that, while at the base pressure begins to fall at 8 A.M., at the top it continues to rise till noon, simply from the mechanical upheaval of the air owing to the higher temperature. In the afternoon, when the minimum at the base falls to −0·020 inch, it is only −0·004 inch at the top, this relatively higher pressure at the top being due to expansion from temperature. The peculiar feature of the pressure curve at the top is essentially a temperature effect.

The diurnal oscillations of the barometer occur alike over the open sea and over the land surfaces of the globe. The atmosphere over the open sea, as already shown, rests on a floor or surface subject to a diurnal range of temperature so small as to render that temperature practically a constant both day and night. This consideration leads to the vital and all-important conclusion that the diurnal oscillations of the barometer are not caused by the heating and cooling of the earth's surface by solar and terrestrial radiation and by the effects which follow these diurnal changes in the temperature of the surface, but that they are primarily caused by the direct and immediate heating by solar radiation, and cooling by nocturnal radiation to the cold regions of space, of the molecules of the air, and of its aqueous vapour. These changes of temperature are instantly communicated through the whole atmosphere from its lowermost stratum resting on the earth's surface to the extreme limit of the atmosphere, which the flight of meteors proves to be not less than 500 miles. There are important modifications affecting the amplitude and times of occurrence of the four prominent phases of the phenomena observed over land surfaces, the temperature of which is being superheated during the day and cooled during the night; but it is particularly to be noted that the barometric oscillations themselves are independent of any changes of temperature of the floor on which the atmosphere rests.

Let us first look at the phenomena in the simplest form as found in the Pacific, or in the midst of the largest water

surface of the globe. The following are the mean variations of pressure from observations made on board the "Challenger," September 1 to 12, 1875, in mean latitude 1° 8′ S. and long. 150° 40′ W., the mean being 29·928 inches:—

	Inch.		Inch.		Inch.
2 A.M.	−0·012	10 A.M.	0·032	6 P.M.	−0·028
4 ,,	−0·022	Noon	0·006	8 ,,	0·004
6 ,,	0·003	2 P.M.	−0·043	10 ,,	0·013
8 ,,	0·028	4 ,,	−0·055	Midnight	0·012

The most striking feature in these oscillations is the amplitude of the range from the A.M. maximum to the P.M. minimum, amounting to 0·087 inch, and the rapidity of the fall from 10 A.M. to 2 P.M. The same feature appears in all means deduced from observations made at least 12° on each side of the equator.

From October 12 to 22, 1875, in mean lat. 35° 1′ S., long. 134° 35′ W., the mean atmospheric pressure was 30·298 inches, and the difference between the A.M. maximum and the P.M. minimum was only 0·036 inch; and from July 12 to 19, 1875, in mean lat. 36° 16′ N. and long. 156° 11′ W., the mean pressure was 30·328 inches, and the difference between the A.M. maximum and P.M. minimum was only 0·025 inch. Thus, with a mean pressure in the Pacific about lat. 35°–36° N. and S. much greater than near the equator, the oscillation is much less, being in the North Pacific less than a third of what occurs near the equator. Similarly, this oscillation is small (or even smaller) in the high-pressure areas in the North and South Atlantic as compared with the same oscillation near the equator.

It is well known that aqueous vapour absorbs the heat rays of the sun considerably more than does the dry air of the atmosphere; how much more physicists have not yet accurately determined. Consequently air heavily charged with aqueous vapour will be heated directly by the sun's rays as they pass through it in a greater degree than comparatively dry air is. Now it is shown further on that the prevailing surface winds outflow in every direction from the areas of high mean pressure in the Atlantic and Pacific about lat. 36° N. and S. Since, notwithstanding, the pressure continues high, it necessarily follows that the high pressure is maintained by an inflow of upper currents, and as the slow descending movement of the air connects the inflowing upper currents with the outflowing prevailing winds of the surface, it follows that the air over high-pressure areas is very dry, and that it is driest where pressure is highest and the high-pressure area best defined. Hence over the best-defined anticyclonic regions the air will be least raised in temperature through all its height by the heat rays of the sun.

On the other hand, between these high-pressure areas of the great oceans there is a belt of comparatively low pressure towards which the north and south trades pour their vapour unceasingly. The atmosphere of this belt of low pressure is thus highly saturated with aqueous vapour which rises in a vast ascending stream of moist air to the higher regions of the atmosphere. These equatorial regions thus present to the sun a highly saturated atmosphere reaching to a very great height. It is in these regions therefore that the atmosphere will be most highly heated by the sun's heat rays as they pass through it. One of the most striking facts of meteorology is the suddenness with which this barometric oscillation increases in amplitude on entering on these parts of intertropical regions; and the rapidity with which its amplitude diminishes on advancing on the high-pressure regions of the horse latitudes is equally striking. The following are the mean oscillations in the middle regions of the four great oceans about lat. 36° from the A.M. maximum to the P.M. minimum about the time of the year in each case when the sun is highest in the heavens:—South Pacific, 0·036 inch; North Pacific, 0·025 inch; South Atlantic, 0·024 inch; and North Atlantic, 0·014 inch. These amplitudes diminish as the ocean becomes more land-locked with continents, or as the anticyclonic region becomes better defined and currents of air are poured down more steadily from the higher regions of the atmosphere.

If the temperature of the whole of the earth's atmosphere were raised, atmospheric pressure would be diminished, for the simple reason that the mass of the atmosphere would thereby be removed to a greater distance from the earth's centre of gravity. Quite different results, however, would follow if the temperature of only a section of the earth's atmosphere were simultaneously raised, such as the section comprised between long. 20° and 60° W. The immediate effect would be an increase of barometric pressure, owing to expansion from the higher temperature; and a subsequent effect would be the setting in of an ascending current more or less powerful, according to the differences between the temperature of the heated section and that of the air on each side. These are essentially the conditions under which the morning maximum and afternoon minimum of atmospheric pressure take place.

The earth makes a complete revolution round its axis in twenty-four hours, and in the same brief interval the double-crested and double-troughed atmospheric diurnal tide makes a complete circuit of the globe. The whole of the diurnal phenomenon of the atmospheric tides is therefore rapidly propagated over the surface of the earth from east to west, the movement being most rapid in equatorial regions, and there the amplitude of the oscillations is greater than in higher latitudes under similar atmospheric, astronomical, and geographical conditions. Owing to the rapidity of the diurnal heating of the atmosphere by the sun through its whole height, some time elapses before the higher expansive force called into play by the increase of temperature can counteract the vertical and lateral resistance it meets from the inertia and viscosity of the air. Till this resistance is overcome, the barometer continues to rise, not because the mass of atmosphere overhead is increased, but because a higher temperature has increased the tension or pressure. When the resistance has been overcome, an ascending current of the warm air sets in, the tension begins to be reduced, and the barometer falls and continues to fall till the afternoon minimum is reached. Thus the forenoon maximum and afternoon minimum are simply a temperature effect, the amplitude of the oscillation being determined by latitude, the quantity of aqueous vapour overhead, and the sun's place in the sky.

All observations show that over the ocean, latitude for latitude, the amplitude of the oscillations is greater in an atmosphere highly charged with aqueous vapour and less in a dry atmosphere. It is also to be noted that in very elevated situations, particularly in tropical regions, the amplitude is greater proportionally to the whole pressure than at lower levels. This is what is to be expected from the law of radiant heat by which more of the heat rays of the sun is absorbed by the air, and particularly by its aqueous vapour, mass for mass, in the higher than in the lower strata.

When the daily maximum temperature is past, and the temperature has begun to fall, the air becomes more condensed in the lower strata, and pressure consequently at great heights is lowered. Owing to this lower pressure in the upper regions of the air, the ascending current which rises from the longitudes where at the time the afternoon pressure is low flows back to eastward, thus increasing the pressure over those longitudes where the temperature is now falling. This atmospheric quasi-tidal movement occasions the P.M. increase of pressure, which reaches the maximum from 9 P.M. to midnight, according

to latitude and geographical position. This maximum is therefore caused by accessions to the mass of the atmosphere overhead, contributed by the ascending currents from the longitudes of the afternoon low pressure immediately to westward.

As midnight and the early hours of morning advance, these contributions become less and less and at length cease altogether, and pressure continues steadily to fall. But between the time when the increase of pressure from the overflow through the upper regions of the atmosphere ceases and the time when pressure increases from the heat rays, direct or indirect, of the returning sun, or during the hours of the night when the effects of nocturnal radiation are the maximum, pressure is still further reduced from another cause. Radiation towards the cold regions of space takes place, not only from the surface of the globe, but also directly from the molecules of the air and its aqueous vapour. The effect of this simultaneous cooling of the atmosphere through its whole height is necessarily a diminution of its tension. Since this takes place at a more rapid rate than can be compensated for by any mechanical or tidal movement of the atmosphere from the regions adjoining, owing to the inertia and viscosity of the air, pressure continues to fall to the morning minimum. This minimum is thus due, not to the removal of any of the mass of air overhead, as happens in the case of the afternoon minimum, but to a reduction of the tension or pressure of the air consequent upon a reduction in the temperature through radiation from the aerial molecules towards the cold regions of space. In the open ocean the morning minimum is largest in the equatorial regions, and it diminishes with latitude; but the rate of diminution with latitude through anticyclonic and other regions is generally less and more uniform than in the case of the afternoon minimum.

The amplitude and times of occurrence of the phases of the diurnal barometric tides are subject to great modifications over the land. The amplitude of the oscillation from the morning maximum to the afternoon minimum is greatest where the atmosphere is driest and the sky clearest, and least where the atmosphere is highly saturated and the sky more frequently and densely covered with clouds, being thus generally the reverse of what is observed to take place over the open sea. The meteorology of India affords the most striking illustrations of this remark. At Bombay in April during the dry atmosphere and clear skies of the north-east monsoon, the oscillation is 0·118 inch; but in July during the humid atmosphere and clouded skies of the south-west monsoon it falls to 0·067 inch. In the Punjab, where the air is drier, it is much greater, rising in exceptional years, such as 1852, to 0·187 inch. The much greater amplitude of this oscillation on land as compared with the open sea is entirely due to the heating of the earth. By this heating of the surface the lower strata of the air become also highly heated and the tension is increased; and, since the air does not expand freely, vertically and laterally, from its inertia and viscosity, the barometer rises. When, however, the resistance is overcome, the ascending current which sets in is stronger owing to its higher temperature. Since this higher temperature which has its origin in the superheated surface is in addition to the direct heating of the air by the heat rays of the sun as they pass through it, the morning maximum and the afternoon minimum over land are both more extreme than over the open sea. It follows that this oscillation is much larger over land, and largest in climates where insolation is strongest.

In places already referred to where the morning maximum is greatly retarded, such as Helder, Sitka, Valentia, and Falmouth, the afternoon minimum in the summer months is singularly small,—so small indeed that it does not fall so low as the mean pressure of the day. This peculiarity in the diurnal barometric tide is in all probability due to their insular position to the westward of a more or less extensive tract of land, by which a tidal overflow is propagated through the upper regions from the continental towards the insular situations. This tidal overflow receives its impulse from the ascending current from the land, which rises sooner and stronger from inland than from insular situations. On the other hand, on the open sea, and away from land in regions where the morning maximum and afternoon minimum are both small, the minimum always falls below the mean of the day, and the time of occurrence of the maximum is not retarded as is the case in insular situations. A map of deviations from the daily mean pressure of the morning minimum in summer shows, as regards the middle and higher latitudes, that it is greatest near the sea, and least in inland continental situations. Indeed in the interior of the Old-World continent the dip in the curve in the early morning is so small that the minimum does not fall below the daily mean pressure, but at most places remains considerably above it. The same relations are seen in north-western Europe, where the morning minimum is − 0·020 inch at Valentia and Falmouth, − 0·018 inch at Helder, and − 0·012 inch at Amsterdam, whilst at Kew it is only − 0·002 inch. From its compact form and relations to the surrounding ocean, the Spanish Peninsula well illustrates the peculiarities of this phase of the pressure. The deviations from the daily mean pressure of the morning minimum are at Lisbon − 0·022 inch and Coimbra − 0·011 inch, but at Madrid in the interior + 0·009 inch,—pressure in the last case, just as happens in the interior of Asia, not falling so low as the daily mean.

The larger minimum near the sea arises from the higher temperature there during the night as compared with more inland situations, from which results a tidal overflow through the upper regions from the sea towards the land, as the temperature of the latter falls lower than the sea during the night. The effect of this overflow is to reduce the pressure over those regions whence it proceeds and to increase it in those regions over which it advances. The shallowing of the morning minimum is greatest in the higher latitudes of continental climates and most complete at great elevations, where in some cases the minimum vanishes,—in other words, where the amount of aqueous vapour is small and the time is short during which no part of the atmosphere overhead is touched by the sun's rays. Since the peculiarity is observable in the curves over nearly the whole continent, appearing even in the low latitudes of Calcutta and Madras, it might be suggested whether we have not evidence here of a vast tidal movement propagated through the higher regions towards that trough-like section of the atmosphere as it moves westwards over the continent where the temperature of the lower strata of the air is about the minimum of the day and pressure also about the minimum.

Reference has been made under ATMOSPHERE to the smallness of the range from the A.M. maximum to the P.M. minimum in the North Atlantic during summer. This phase in the diurnal distribution of pressure is represented in fig. 3, which shows for June the mean amount of the oscillation by lines of 10, 20, 40, 60, 80, and 100 thousandths of an inch, or 0·010 inch, 0·020 inch, &c. This abnormality begins in March, attains the maximum in June, and terminates in October. It is thus confined to the warmer months of the year, and, unlike most meteorological phenomena, is not cumulative, but follows the sun, so that its maximum occurs in June, and not in July as that of the temperature of the air, or in August as

the temperature of the sea. The smallness of this range over the North Atlantic, which is less than occurs in any other ocean in the same latitudes, is to a large extent caused by the small dip in the diurnal curve of the afternoon minimum.

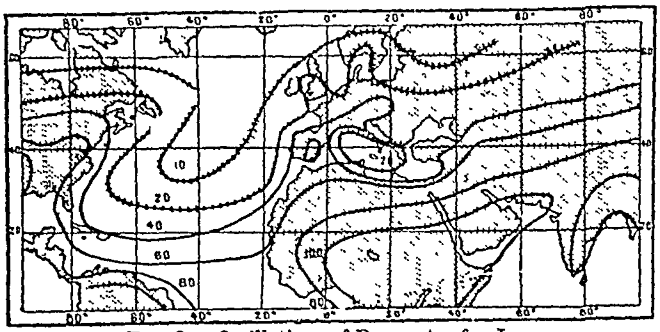

Fig. 3.—Oscillations of Barometer for June.

If the map of the distribution of pressure over the globe for July be examined (fig. 17) it is seen that this part of the Atlantic is occupied by a well-defined area of high mean pressure,—higher indeed than occurs at any season over any ocean; and it is shown below that out of this area the surface winds blow in all directions. But, since air is constantly being drained out of this region by the wind without diminishing the pressure, it follows of necessity that the high pressure must be maintained by accessions of air received from above through the upper currents. Now the regions whence such accessions can come are the upper currents which have their origin in the ascending currents that rise from the heated plains of Africa, Europe, the belt of calms, and the two Americas surrounding the North Atlantic. It is evident that the major portion of each day's overflow of air from the continents through the upper regions of the air upon the Atlantic, whether this overflow takes place by convection currents or from a tidal movement similar to what has been already described, will take place during mid afternoon. In other words, the overflow will occur about the time of the afternoon minimum of the Atlantic, thus diminishing the dip of this minimum, and so producing the abnormally small range now under examination. It is in favour of this view that the abnormality follows the sun's course and is not cumulative, and is felt also on both sides of the Atlantic, even although the weather on the east side is dry and all but rainless, and on the west moderately moist and characterized by a rather copious rainfall. It is also full of significance that the peculiarity is most strikingly seen in that part of the ocean of the globe which is closely hemmed in by large masses of land.

Influence of the Moon on Atmospheric Pressure.—Fifteen years' hourly observations have been made at Batavia and discussed by the late Dr Bergsma in their relation to the lunar day, which was assumed in the calculations to commence with the time of the upper transit of the moon. The result of the inquiry is that atmospheric pressure at Batavia has a lunar tide quite as distinctly marked as the ordinary diurnal barometric tide, except that its amplitude is much less. The four phases are these:—

1st max.	+ 0·0022	inch at lunar hour	1
1st min.	− 0·0021	,, ,, ,,	7
2d max.	+ 0·0025	,, ,, ,,	13
2d min.	− 0·0024	,, ,, ,,	19

The lunar tide has the important difference that its phases follow the moon's apparent course much more closely than the ordinary diurnal fluctuations of the barometer follow that of the sun. The two maxima occur about the 1st and 13th, and the two minima about the 7th and 19th, whereas about four daily phases of the diurnal barometric fluctua- is highest with respect to the sun's apparent course from one to six hours later. It is interesting to note that in the higher latitudes in inland situations during winter, or at times and in situations where the disturbing influences of temperature and humidity tend towards a minimum, the times of occurrence of the four phases of the daily oscillation of the barometer approximate to those of the daily lunar atmospheric tide.

Since a distinct lunar tide is traced to the attractive influence of the moon, it follows that the attractive influence of the sun will enter as one of the several causes which determine the phases and amplitude of the diurnal barometric curve. It also follows from the much less attractive influence of the sun than that of the moon on the earth's atmosphere that the effects of the sun's attraction on the pressure will be wholly concealed by the much larger effects of the other forces concerned in determining the diurnal oscillation, except in the case or cases where the variation in the fluctuation is small at 1 and 7 A.M. and 1 and 7 P.M. Now at places north of lat. 45° N. the variation at 1 A.M. is small during the winter, and it is a singular fact that some years ago Rykatchew of St Petersburg drew the attention of meteorologists to the existence at these northern stations of a faintly marked third maximum; and it is further of importance to remark that, at many places where on the mean of years the third maximum is scarcely or not at all marked, it appears in the mean of some of the separate years. Thus, though it does not appear in the mean of the twenty years ending 1873 at Greenwich for January, it appears in nine of the individual years. It is highly probable that this maximum, which may be named Rykatchew's maximum from its discoverer, is due to the attractive influence of the sun, its amplitude and time of occurrence being in accordance with such a supposition.

Diurnal Variation of the Force of the Wind.—During the three and a half years' cruise of the "Challenger," ending with May 1876, observations of the force and direction of the wind were made on 1202 days, at least

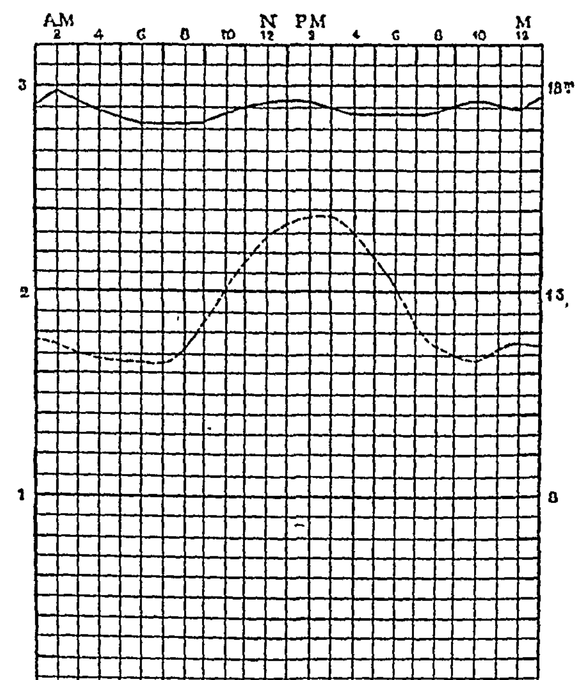

Fig. 4.—Diurnal Force of Wind at Sea and near Land.

twelve times each day,—650 of the days being on the open sea and 552 near land. The observations of force were made on Beaufort's scale 0–12, being the scale of wind-force observed at sea. The mean diurnal force of the wind on the open sea and near land respectively is shown

in fig. 4, where the figures on the left are Beaufort's scale, and those on the right the equivalents in miles per hour. The solid line shows at the different hours of the day the mean force on the open sea, and the dotted line the mean force near land.

As regards the open sea it is seen that the diurnal variation is exceedingly small, there being two apparent slight maxima, about midday and midnight respectively. On examining, however, the separate means for the North and South Atlantic, North and South Pacific, and the Southern Ocean, there is no uniform agreement observable among their curves, the slight variations which are met with being different in each case. It follows therefore that the force of the winds on the open sea is subject to no distinct and uniform diurnal variation. The difference between the hour of least and greatest mean force is less than a mile per hour.

Quite different is it, however, with the winds encountered by the "Challenger" near land, the force of the wind there giving a curve as pronouncedly marked as the ordinary diurnal curve of temperature. The minimum occurs at 2 to 4 A.M. and the maximum from noon to 4 P.M., the absolute highest being at 2 P.M. The curves constructed for each of the five oceans from the observations near land give one and the same result, or a curve closely accordant with the curve of diurnal temperature. The differences between the hours of least and greatest force are as follows:—Southern Ocean $6\frac{1}{2}$ miles, South Pacific $4\frac{1}{2}$ miles, South Atlantic $3\frac{1}{4}$ miles, and North Atlantic and North Pacific 3 miles per hour.

In the case of each ocean the velocity of the wind on the open sea is considerably in excess of that near land, but in no case does the maximum velocity near land, attained about midday, reach the velocity of the wind on the open sea. The 650 daily observations on the open sea give a mean hourly velocity of $17\frac{1}{2}$ miles, whereas the 552 near land give a velocity of only $12\frac{1}{2}$ miles per hour. The difference is greatest at 4 A.M., when it amounts to upwards of 6 miles an hour, but is diminished by the rising temperature till at 2 P.M. it is less than 3 miles an hour.

At Mauritius, which is situated within the south-east trades, the minimum velocity of the wind is 9·7 miles per hour, occurring from 2 to 3 A.M., from which it rises to the maximum 18·5 miles from 1 to 2 P.M., the influence of the sun being thus to double the wind's velocity. At Batavia, situated in a region where the mean barometric gradient is much smaller, the differences are still more decided. From 1 to 6 A.M. 85 per cent. of the whole of the observations are calms, whereas from noon to 2 P.M. only 1 per cent. are calms. In all months, the minimum velocity occurs in the early morning, when the temperature is lowest, and the maximum from 1 to 3 P.M., when the temperature is highest, the mean minimum and maximum velocities being to each other as 1 to 21. At Coimbra the mean maximum hourly velocity is five times greater than the minimum hourly velocity in summer, whereas in winter it is only about a half more. At Valentia, in the southwest of Ireland, one of the windiest situations in western Europe, the three summer months of 1878 gave a mean hourly velocity of 13·3 miles per hour, the minimum oscillating from 10 to 11 miles an hour from 9 P.M. to 6 A.M., and the maximum exceeding 16 miles an hour from 11 A.M. to 5 P.M. The absolute lowest hourly mean was 10 miles at 11 P.M., and the highest 18 miles at 1 P.M., the velocity about midday being thus nearly double that of the night. Many observations might be added to these, including those published by Hann, Köppen, Hamberg, and others, which go to establish the fact that the curves of the diurnal variation of the velocity of the wind generally conform to the diurnal curves of temperature. The curves are most strongly marked during the hottest months; and the maximum velocity occurs at 1 P.M. or shortly thereafter, being thus before the time of occurrence of the maximum temperature of the day, and the minimum in the early morning, or about the time when the temperature falls to the lowest. The rule also holds good with all winds, whatever be their direction. The exceptions to this rule are so few and of such a kind that they are probably to be attributed to causes more or less of a local character.

Hann has shown, for a number of places in northern Europe, that with a clear sky the velocity is doubled from the minimum to the maximum, with a sky half covered the velocity is three-fourths greater, and with a sky wholly covered the velocity is only a half more. On the other hand at the strictly inland situation of Vienna, with a clear sky the velocity is double, and with a sky half covered it is two-thirds greater, but with a covered sky the diurnal variation in the wind's velocity becomes irregular and faintly marked. Hann has also examined the winds at Vienna, and found that winds of a velocity not exceeding 30 kilometres an hour show a mean diurnal increase from 11 kilometres at 6 A.M. to 16·8 at 1 P.M., but that winds of velocity exceeding 30 kilometres an hour exhibit only a faintly marked and irregular increase of velocity during the day.

In offering an explanation of this remarkable fact regarding the diurnal variation in the velocity of the wind in all climates, it is to be remarked that the minimum velocity occurs when terrestrial radiation and its effects are greatest, but the increase of the velocity closely follows the sun, and the maximum is reached nearer the time the sun crosses the meridian than perhaps any of the other maxima or minima of meteorology which are dependent on the sun's diurnal course. It is also to be noted that the winds over the open sea are practically uninfluenced by solar and terrestrial radiation, for there the diurnal curve of variation in the force of the wind is all but a straight line. On nearing land, however, the wind's force exhibits a diurnal curve of variation as distinctly marked as, and bearing a close resemblance to, the analogous curve of temperature; while on the land itself these features become still more decidedly pronounced. Lastly, the amount of the diurnal variation of the temperature of the surface of the sea is less than a degree, whereas over all land surfaces the diurnal variation of the temperature is large, even where the ground is covered by vegetation, and enormously large over sandy wastes.

From this it follows that, so far as concerns any direct influence on the air itself, solar and terrestrial radiation exercise no influence on the diurnal increase of the velocity of the air with the increase of its temperature,—or, if any influence at all, such influence must be altogether insignificant, as is conclusively shown by the wind observations of the "Challenger" over each of the five great oceans of the globe. The same observations show that on nearing land the wind is everywhere greatly reduced in force. The retardation is greatest during the hours when the daily temperature is at the minimum; and it is particularly to be noted that, though the temperature rises considerably, no marked increase in the velocity sets in till about 9 A.M., when the temperature has begun to rise above the daily mean. From this time the increase is rapid (see fig. 4); the maximum is reached shortly after the period of strongest insolation; and the velocity falls a little (but only a little) during the next three to five hours, according to season, latitude, and position, and falls again to near the minimum shortly after the hour when the temperature is at the mean. Even at the maximum, the velocity near land falls considerably short of the velocity which is steadily maintained over the open sea by night as well as by day.

The period of the day when the wind's velocity is increased is practically limited to the hours when the temperature is above the daily mean, and the influence of this higher temperature is to counteract to some extent the retardation of the wind's velocity resulting from friction and from the viscosity of the air. The increase in the diurnal velocity of the wind is in all probability due to the superheating of the surface of the ground and to the consequent ascensional movement of the air, tending to counteract the effect of friction and of viscosity between the lowermost stratum of the air and the ground. It is of importance in this connexion to keep in view the fact that in cloudy weather a temperature much higher than might have been supposed is often radiated from the clouds down upon the earth's surface,[1] which accounts for the phenomenon of the

[1] *Journal of Scottish Meteorological Society*, vol. ii. p. 280.

diurnal variation in the wind's velocity occurring frequently also in cloudy weather. On the other hand, during the night, when terrestrial radiation is proceeding, the temperature of the surface falls greatly, and instead of an ascensional movement in the lower stratum of the air there is rather a tendency towards a descensional movement (if the wind be light there is an actual movement) of the lowest air stratum down the slopes of the country; and since the friction between the wind and the surface of the earth is thereby increased the diurnal velocity of the wind falls to the minimum during these hours (see also p. 156).

Among the most marked exceptions to the general rule of the diurnal distribution of wind force may be cited the bitterly cold furious blasts of wind encountered in narrow valleys in such mountainous regions as the Alps during clear and comparatively calm nights. These are simply the out-rush of the cold air poured into the upper basins of the valleys by the descensional currents from the slopes which the chilling effects of terrestrial radiation set in motion. On the other hand, the air of the valleys becomes heated and expands during the day, thus giving rise to a warm wind blowing up the valleys, which, on account of the vapour it carries with it from the lower levels, frequently covers the higher slopes and tops of the mountains with cloud and drizzling rain.

Diurnal Variation in the Direction of the Wind.—In all climates near seas and other large sheets of water, where the distribution of atmospheric pressure is tolerably equable, or the barometric gradient small, and the sun heat moderately strong, land and sea breezes are of daily occurrence. In such places a breeze from the sea gradually sets in in the morning, which gradually rises to a stiff breeze during the heat of the day and again towards evening sinks to a calm. Soon after this a breeze sets in from the land, blows strongly seaward during the night, and dies away in the morning, giving place to the sea breeze as before. These breezes are occasioned by the surface of the land being heated in a much higher degree than that of the sea during the day; the air over the land being thereby made lighter ascends, and its place is supplied by the cooler air of the sea breeze drawn landward, and partly also by descending currents, as shown by the humidity observations of the "Challenger," which indicate increasing dryness when the sea breeze is strongest. Again during the night the temperature of the land and of the air over it falls below that of the sea, and the air of the land thus becoming heavier and denser flows over the sea as a land breeze. As the best-marked and most frequently occurring cases of the sea breeze begin some distance out at sea and gradually approach the land, it is very probable that, as suggested by Blanford, the ascending heated air flows seaward as an upper current, and that the increased barometric gradient thus caused largely accounts for these breezes.

Sea and land breezes are thus determined by the relative positions of the land and its coasts, subject to a further modification arising from the rotation of the earth. Thus on the coast of the Gulf of Lyons the sea breeze from the south veers to south-west and dies away as a west wind, while the land breeze from the north gradually veers to north-east and dies away as an east wind. On the coast of Algeria, on the other hand, the sea breeze veers from north to north-east and dies away in the east, whereas the south land breeze veers to south-west and dies away in the west. Sea breezes also occur in such unsettled climates as that of Scotland, when the weather conditions are favourable. These conditions are presented when an anticyclone overspreads the country, with its accompanying fine settled weather, small variation in the distribution of atmospheric pressure, clear skies, and consequently strong sunshine. Under these conditions the following are the veerings of the wind off the coast of Berwickshire. In the morning the wind is north-west till about 10 A.M., when it veers to north, falling all the time till finally it sinks to a calm. A little before noon it springs up from north-east or east, veers to south-east from 2 to 3 P.M., where it continues till 7 P.M., about which time it veers to south and then south-west, diminishing in force and finally sinking to a calm. About sunset it springs up from west, veering to north-west during the night, where it continues till the following morning. The wind thus virtually makes the round of the compass, is strongest from north-west and south-east and weakest at north-east and south-west, being thus strongest when its course is perpendicular to the line of coast.

The observations made by the "Challenger" in the region of the north-east trades in 1873 show a small diurnal variation in the direction of the wind, the variation being from E. 47° 5′ N. at 2 to 6 A.M. to E. 56° N. at 10 A.M. to 2 P.M., the variation being thus 8° 55′ towards north during the hottest hours of the day. At Mauritius observatory, which is several miles from the sea, the daily period in the direction of the wind is from E. 22° 15′ S. at 4 A.M., being the most southerly point, to E. 7° S. at 1 P.M., and thence back to E. 22° 15′ S. at 4 A.M. The diurnal variation is 15° 15′, and thus the influence of the sun impresses on the wind at this observatory a more truly easterly character.

At the Austrian naval station at Pola, near the head of the Adriatic, the daily variation in the direction of the wind is well-marked. Starting from a point east of south at 5 A.M., it gradually veers round to westward, the most westerly point, almost due west, being reached at 5 to 6 P.M., after which it gradually shifts back to its starting point in the morning. Here we have evidently a diurnal wind-system different from that of the land and the sea breeze. Pola is situated near the south-western extremity of the peninsula of Istria, and the direction in the early morning of east by south is the direction the wind would take if a small anticyclone overspread the peninsula; and the direction from the west in mid afternoon is the direction the wind would have at Pola if the peninsula were occupied by a small cyclone with the lowest pressure in the centre. Now the influence of solar radiation is to form, through the ascending current from the heated land, a diminution of pressure over the land,—in other words, what is essentially a cyclone. On the other hand, during the night the influence of terrestrial radiation is to generate, through the cooling of the land and the air resting above it, a relatively higher atmospheric pressure in the interior of the peninsula with its characteristic system of outblowing winds.

At Coimbra, in July 1878, the diurnal variation of the wind's direction was from W. 49° 37′ N. at 2 to 6 A.M. to W. 33° 15′ N. at 4 to 6 P.M., the amount of the variation being thus 16° 22′ in the direction of west. At Valentia, in the south-west of Ireland, during the summer months of 1878 the diurnal variation of the wind's direction was from W. by S. at 7 to 9 A.M. to S.W. by W. at 5 to 7 P.M. The variation was thus from a point nearly south to a point nearly south-west, or through nearly 45° in the direction of west. On the other hand, at Aberdeen during the same months of 1878, the diurnal variation of the wind's direction was from S.W. at 6 to 7 A.M. to S. by E. at 12 to 4 P.M., the variation being thus 56° from south-west in the direction of east through south. Attention is here drawn to the exactly opposite ways in which the diurnal veering or shifting of the wind takes places at Valentia and Aberdeen, but particularly to the important circumstance that in each case the diurnal changes in the wind's direction which actually occur are precisely those that would take place on the supposition that during the hottest hours of the day an ascensional movement of the air sets in from the heated lands of the British Islands, and that an in-draught takes place all round, which with the descending currents makes good the loss caused by the up-draught. Thus then both the diurnal increase in the wind's velocity and the change in its direction which observation shows to take place during the hottest hours of the day are traced to the same cause, viz., the heating of the surface by the sun, the heating of the lowest stratum of air resting on the surface, and the ascensional movements which are the necessary result.

It is instructive to note that at Nukuss, at some distance to the south of the Sea of Aral, where the summer direction of the wind is northerly, the north component is at the daily maximum at 4 P.M., having shifted into this direction from north-east, where it is at 9 A.M. Much or nearly everything remains to be done in working out this problem in its practical details as one of the important elements of climatology, with the view of arriving at some definite knowledge of the influence of physical configuration and different vegetable coverings of the surface on radiation and on the velocity and direction of the wind.

Diurnal Variation in the Amount of Cloud.—Mists and fogs are visible vapours floating in the air near the surface of the earth, and clouds are visible vapours at a considerable height. These forms of visible vapour are all produced by whatever lowers the temperature of the air below the dew point,—such as radiation from the molecules of the atmosphere towards the cold regions of space, the simple

expansion of the air of ascending currents, the mixing of cold air with air that is warm and moist, and the cooling of the air in contact with the surface of the earth when its temperature has been lowered by nocturnal radiation.

The forms of clouds are endless. Since clouds are subject to certain distinct modifications from the same causes which produce other atmospheric phenomena, the face of the sky may be regarded as indicating the operation of these causes, just as the face of man indicates his mental and physical states. Hence the importance of the study of clouds, and hence the necessity of a nomenclature of clouds as the basis of accurate and comparable observations. An adequate nomenclature of clouds is still a desideratum. Luke Howard's classification, which continues to hold its ground as a provisional nomenclature, was proposed by him in 1803, and by it clouds are considered as divided into seven kinds. Of these, three are simple forms, the *cirrus*, the *cumulus*, and the *stratus*; and four intermediate or compound, the *cirro-cumulus*, the *cirro-stratus*, the *cumulo-stratus*, and the *cumulo-cirro-stratus*, *nimbus*, or *rain cloud*.

The cirrus cloud consists of wavy, parallel, or divergent filaments, which may increase in any or all directions. It is the cloud of the least density, the greatest elevation, and the greatest variety of figure. It is probable that the particles composing it are minute crystals of ice or snow-flakes. The cirrus is intimately connected with the great movements of the atmosphere; and it is solely from the movements of the cirrus that we have any direct knowledge of the upper currents of the atmosphere. In recent years much has been done, particularly by Professor Hildebrandsson of Upsala and Clement Ley, in investigating the relations of this cloud to storms and other changes of weather.

The cumulus is the name applied to those convex or conical heaps of clouds which increase upwards from a horizontal base. They are generally of a very dense structure, are formed in the lower regions of the atmosphere, and are carried along by the aerial current next the earth. They form the tops of the ascending currents which rise from the heated ground, and have a diurnal period so well marked that they are often named the "cloud of the day." The form of stratus comprehends those mists and fogs which in the calm evening of a warm summer day make their appearance in the bottom of valleys and over low-lying grounds, and sometimes spread upwards over the surrounding country like an inundation; they have an equally well marked daily period, and are frequently called the "cloud of night." The cirro-cumulus is made up of small roundish masses, lying near each other, and quite separated by intervals of sky. It may be considered as formed from the cirrus by the fibres of that cloud breaking, as it were, and collapsing into roundish masses, thus destroying the texture but retaining the arrangement of that cloud. This singularly beautiful cloud is commonly known as a mackerel sky, and is of most frequent occurrence during dry warm summer weather. The cirro-stratus consists of horizontal masses thinned towards the circumference, bent downwards or undulating, and either separate or in groups. Since this cloud has great extent and continuity of substance, but little perpendicular depth or thickness, it is the cloud which most frequently fulfils the conditions for the phenomena of coronæ, solar and lunar halos, parhelia or mock suns, and paraselenæ or mock moons. The cumulo-stratus is formed by the cirro-stratus blending with the cumulus, or spreading underneath it as a horizontal layer of vapour. The cumulo-cirro-stratus, or nimbus, is the well-known rain-cloud, which consists of a cloud or system of clouds from which rain is falling. At a considerable height a sheet of cirro-stratus cloud is extended, under which cumulus clouds drift from windward; these rapidly increasing unite and appear to form one continuous grey mass from which the rain falls. The breaking up of the lower grey mass indicates that the rain will soon cease. When a rain-cloud is seen at a distance, cirri appear to shoot out from its top in all directions; and it is observed that the more copious the rainfall the greater is the display of cirri. The cirrus, cirro-cumulus, cirro-stratus, cumulo-stratus, and nimbus are connected more or less closely with the great atmospheric movements of the cyclone and anticyclone. In what follows here only the amount of sky covered will be taken into account, and not the species of cloud covering.

The diurnal variation in the amount of cloud in the sky on the open sea is very small. The following are the means of two hundred and seventy-seven days' observations on board the "Challenger," stated in percentages of sky covered:—

2 A.M.	59	10 A.M.	58	6 P.M.	57
4 ,,	59	Noon	56	8 ,,	57
6 ,,	62	2 P.M.	58	10 ,,	57
8 ,,	62	4 ,,	59	Midnight	57

Two maxima are here indicated, the one about or shortly after sunrise and the other in the early part of the afternoon; and two minima, the one at noon and the other from sunset to midnight. The difference between the extremes is only 6 per cent. of the sky.

At Batavia the daily maximum is from 6 to 11 P.M., and the minimum from 8 to 11 A.M., the extremes being 52 per cent. at 9 A.M. and 69 per cent. at 7 P.M.,—a difference of 17 per cent. Of four daily observations at Mauritius, the maximum is 50 per cent. at 1 P.M. and the minimum 38 per cent. at 6 A.M. At Coimbra, observations of clouds have been made five times daily, and six years' results give the maximum 63 per cent. at 9 P.M. and the minimum 52 per cent. at 9 A.M. At this place, during July and August, the greatest amount of cloud occurs at 6 P.M., and in these months the rainfall at Coimbra is very small. The minimum is more pronounced at 9 A.M. than at any other period; in winter this phase occurs about four hours later. At the continental situation of Vienna, during the warm months of the year the maximum is at 2 P.M., with a secondary maximum about 6 A.M., and the minimum from 10 P.M. to 2 A.M.; but during the cold months the maximum is at 6 A.M. and the minimum during the evening and night. In the Rocky Mountains, the chief maximum, 57 per cent., is at 3 P.M., with a secondary one 30 per cent. at 5 A.M.; and the chief minimum 20 at 3 A.M. and a secondary one 29 at 11 P.M. At Helsingfors the maximum of cloud occurs from 10 A.M. to 2 P.M., and the minimum from 10 P.M. to 2 A.M.

Much yet remains to be done with regard to the determination of the diurnal variation of cloud, but from the above one or two deductions of a general character may be drawn. A maximum occurs in the morning and continues till shortly after the sun has risen, and this maximum is more decidedly pronounced over the open sea than over land. Its appearance is without a doubt due to the general cooling of the atmosphere through its whole height by terrestrial radiation, and its disappearance to the heating of the air, which commences about sunrise. Then follows one of the diurnal minima, which continues till midday, or a little later; in other words, it continues till, owing to the diurnal heating of the air by the sun, the ascending current has fairly set in. The period of this ascending current marks the second maximum, which during the warmer months is larger than the morning maximum over land. The cumulus is the characteristic cloud of this maximum. These clouds are merely the summits of the ascending currents which rise from the heated land, where the aqueous vapour is condensed in cloud by the expansion which takes place with increase of height.

These cumulus clouds throw a not unimportant light on the behaviour of the ascending currents which rise from the surface when heated by the sun,—inasmuch as they

during the six months from October to March. The mean of the six hottest months shows the maximum to take place from 3 to 4 P.M. and the minimum from 4 to 5 A.M., these being the times of occurrence of the two minima of pressure. At this season, however, the morning minimum pressure is but faintly marked in such climates as those of Siberia. During the twelve hours from 9 A.M. to 9 P.M., when the temperature is above the daily mean, 717 of the whole number occurred, thus leaving only 139 for the twelve hours when the temperature is below the daily mean. The great majority of the thunderstorms occur during the part of the day when the ascensional movement of the air from the heated ground takes place, and they attain the maximum when the temperature and this upward movement are also at the maximum. Owing to the westerly winds from the Atlantic which prevail over Europe and western Siberia during summer, the maximum rainfall of the year occurs over this extensive region in this season; and the importance and significance of the inquiry into this element of climate lie in the fact that the greater portion of the summer rains is discharged over these regions by the thunderstorm. The "Challenger" observations on the open sea show the maximum occurrence of thunderstorms to be from 10 P.M. to 8 A.M., 22 being observed during these ten hours and 10 during the other fourteen hours of the day,—a result which suggests that over the ocean terrestrial radiation is more powerful than solar radiation in causing vertical disturbances in the equilibrium of the atmosphere.

Atmospheric vapour and ascending currents thus play an important part in the history of these thunderstorms. Where the climate is dry and rainless, like that of Jerusalem in summer, thunder is altogether unknown. On the other hand, where during a particular season an anticyclone with its vast descending current in the centre remains over a region, as happens over the centre of the old continent during the winter, over that region thunder is equally unknown during that season. Further, in such places as Lisbon and Coimbra, where the summer rainfall is small and its occurrence infrequent, thunderstorms become less frequent, and the hours of their occurrence are later in the day than they are before and after the dry season.

The thunderstorms at Mauritius call for special notice. There are two maxima in the diurnal curve, the larger from noon to 4 P.M. and the smaller from 3 to 6 A.M., which are near the times of the barometric minima; and two minima, from 9 P.M. to 1 A.M. and from 8 to 10 A.M., these being near the times of the barometric maxima. But the important point as regards the thunderstorms of Mauritius is that for twelve years none were recorded in June and July, one only in August, one in September, and three in October. The annual period of the thunderstorms of this island extends from near the end of October to the middle of May, or during the time of the greatest rainfall, practically none occurring during the rest of the year. But rain continues to fall during the four months of no thunder, the mean monthly rainfall being then about 2 inches, falling, however, in September to 1·37 inches. During these four months, therefore, there is in the air the aqueous vapour, and, these being dry months, there is the condition of ascending currents. There appears, however, to be then wanting another element which seems essential to the electrical manifestations of the thunderstorm, viz., the conditions which give masses of descending cold air along with the ascending current of warm moist air. During the months when thunder is of no unusual occurrence the high pressure of Asia repeatedly advances, as Dr Meldrum has pointed out, close on Mauritius; and so frequently is this the case that he considers the belt of calms between the two trade winds to stretch in a slanting direction from Madagascar to Ceylon. As long as this state of things occurs with more or less frequency, the conditions of a descending cold current of large volume are provided, and thunderstorms occur. But during June, July, August, and September, when atmospheric pressure is low in Central Asia, and there is an unbroken increase of pressure from Asia southwards to Mauritius, and while Mauritius remains in the heart of the south-east trades, the conditions of descending cold currents of any considerable volume are not present, and thunder is there unknown at that season.

Now in situations which afford the three conditions of aqueous vapour, ascending currents, and descending cold currents, whilst the diurnal and annual periods are quite distinctly marked, the phenomena are more uniformly distributed through the hours of the day and months of the year than elsewhere. Pola and Fiume, at the head of the Adriatic, being shut in and encompassed by lofty Alps, are illustrations. At Fiume the greater maximum occurs from 11 A.M. to 4 P.M. and the smaller from 2 to 4 A.M., and the minima from 10 P.M. to 1 A.M. and 5 to 9 A.M. While during the twelve hours the temperature is above the mean of the day from May to September the number of the thunderstorms here was 245 for the nine years ending 1879, the number during the twelve hours the temperature is under the mean was 185. The comparatively large number during the colder hours of the night is no doubt due to the warm moist atmosphere of this confined sea and the close proximity of the Alps.

There is still another set of conditions favouring the development of thunderstorms in certain climates which the observations made at Stykkisholm in the north-west of Iceland illustrate. During the fourteen years ending 1879 there occurred here twenty-three thunderstorms, but there was only one in the six warm months from April to September; in other words, the thunderstorms of this climate are essentially winter phenomena. Further, of the twenty-three hours in which they occurred, only three were at a time of the day when the sun was above the horizon, viz., twice in March and once in September; in other words, the thunderstorms of Stykkisholm are nocturnal phenomena. It is instructive to observe that in the north and north-west of Scotland thunder occurs most frequently during the night and in winter, whereas in central, southern, and eastern districts it occurs most frequently during the day and in summer,—the thunderstorms in the former case approximating in type to those of Iceland and in the latter to those of Ekaterinburg. A little reflexion shows that in north-western Europe it is during winter and during night that warm moist ascending and cold dry descending currents are most frequently brought into close proximity during the great Atlantic storms of the season; and it is at the changes of wind, humidity, and temperature accompanying the passage of the centres of the cyclones that the thunder peals are heard. On the other hand, in the east and south of Scotland it is during the hot months of the year that these ascending columns of warm moist air and descending columns of cold dry air are most frequently brought together, and there, accordingly, thunder with the heavy rains which accompany it is of most frequent occurrence from 11 A.M. to 5 P.M. from May to September. These essentially different types of thunderstorms have been classed by Mohn as heat thunderstorms and cyclonic thunderstorms.

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during the six months from October to March. The mean of the six hottest months shows the maximum to take place from 3 to 4 P.M. and the minimum from 4 to 5 A.M., these being the times of occurrence of the two minima of pressure. At this season, however, the morning minimum pressure is but faintly marked in such climates as those of Siberia. During the twelve hours from 9 A.M. to 9 P.M., when the temperature is above the daily mean, 717 of the whole number occurred, thus leaving only 139 for the twelve hours when the temperature is below the daily mean. The great majority of the thunderstorms occur during the part of the day when the ascensional movement of the air from the heated ground takes place, and they attain the maximum when the temperature and this upward movement are also at the maximum. Owing to the westerly winds from the Atlantic which prevail over Europe and western Siberia during summer, the maximum rainfall of the year occurs over this extensive region in this season; and the importance and significance of the inquiry into this element of climate lie in the fact that the greater portion of the summer rains is discharged over these regions by the thunderstorm. The "Challenger" observations on the open sea show the maximum occurrence of thunderstorms to be from 10 P.M. to 8 A.M., 22 being observed during these ten hours and 10 during the other fourteen hours of the day,—a result which suggests that over the ocean terrestrial radiation is more powerful than solar radiation in causing vertical disturbances in the equilibrium of the atmosphere.

Atmospheric vapour and ascending currents thus play an important part in the history of these thunderstorms. Where the climate is dry and rainless, like that of Jerusalem in summer, thunder is altogether unknown. On the other hand, where during a particular season an anticyclone with its vast descending current in the centre remains over a region, as happens over the centre of the old continent during the winter, over that region thunder is equally unknown during that season. Further, in such places as Lisbon and Coimbra, where the summer rainfall is small and its occurrence infrequent, thunderstorms become less frequent, and the hours of their occurrence are later in the day than they are before and after the dry season.

The thunderstorms at Mauritius call for special notice. There are two maxima in the diurnal curve, the larger from noon to 4 P.M. and the smaller from 3 to 6 A.M., which are near the times of the barometric minima; and two minima, from 9 P.M. to 1 A.M. and from 8 to 10 A.M., these being near the times of the barometric maxima. But the important point as regards the thunderstorms of Mauritius is that for twelve years none were recorded in June and July, one only in August, one in September, and three in October. The annual period of the thunderstorms of this island extends from near the end of October to the middle of May, or during the time of the greatest rainfall, practically none occurring during the rest of the year. But rain continues to fall during the four months of no thunder, the mean monthly rainfall being then about 2 inches, falling, however, in September to 1·37 inches. During these four months, therefore, there is in the air the aqueous vapour, and, these being dry months, there is the condition of ascending currents. There appears, however, to be then wanting another element which seems essential to the electrical manifestations of the thunderstorm, viz., the conditions which give masses of descending cold air along with the ascending current of warm moist air. During the months when thunder is of no unusual occurrence the high pressure of Asia repeatedly advances, as Dr Meldrum has pointed out, close on Mauritius; and so frequently is this the case that he considers the belt of calms between the two trade winds to stretch in a slanting direction from Madagascar to Ceylon. As long as this state of things occurs with more or less frequency, the conditions of a descending cold current of large volume are provided, and thunderstorms occur. But during June, July, August, and September, when atmospheric pressure is low in Central Asia, and there is an unbroken increase of pressure from Asia southwards to Mauritius, and while Mauritius remains in the heart of the south-east trades, the conditions of descending cold currents of any considerable volume are not present, and thunder is there unknown at that season.

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humidity diminish with height at an abnormally rapid rate. Cyclones are thus phenomena resulting from a disturbance of the equilibrium of the atmosphere considered horizontally, but whirlwinds and tornadoes have their origin in a vertical disturbance of atmospheric equilibrium.

Among the most remarkable of the tornado-swept regions of the globe are certain portions of the United States; and to the examination of these the meteorological service of the States has given special attention by a systematic, careful, and minute observation of the attendant phenomena and the destructive effects. The tornadoes of the last eighty-seven years, numbering about six hundred, have been classed under the different States where they are reported to have occurred, and fig. 5 shows this relative distribution over the States. The areas of greatest frequency are at long distances from each other. That part of the great basin lying west of the Mississippi, including the States of Iowa, Missouri, Kansas, and Nebraska, is the region in which tornadoes are most frequent. Tornadoes occur at all seasons, being most frequent, however, from April to September, and least frequent in December and January.

The hour of occurrence of one hundred and sixty-two of the tornadoes is given in the official report as follows:—

Midt. to 2 A.M.	2	8 A.M. to 10 A.M.	1	4 P.M. to 6 P.M.	52
2 A.M. ,, 4 ,,	5	10 ,, ,, Noon	7	6 ,, ,, 8 ,,	17
4 ,, ,, 6 ,,	3	Noon ,, 2 P.M.	13	8 ,, ,, 10 ,,	7
6 ,, ,, 8 ,,	4	2 P.M. ,, 4 ,,	47	10 ,, ,, Midt.	4

Thus the diurnal period of tornadoes is analogous to the period for temperature, wind velocity, and thunderstorms. The atmospheric conditions which appear invariably to precede the formation of the tornado are violent contrasts of temperature and humidity immediately to the north and south of the path to be traversed by the storm. It is highly interesting to observe from fig. 5 that the region of most frequent occurrence of tornadoes is the region where a large number of the cyclones of the United States appear to originate (and the same region Loomis has shown to be remarkable for violent contrasts of temperature occurring within limited spaces and times), and that, as appears in the regions of the Alleghanies, they decrease in frequency with height.

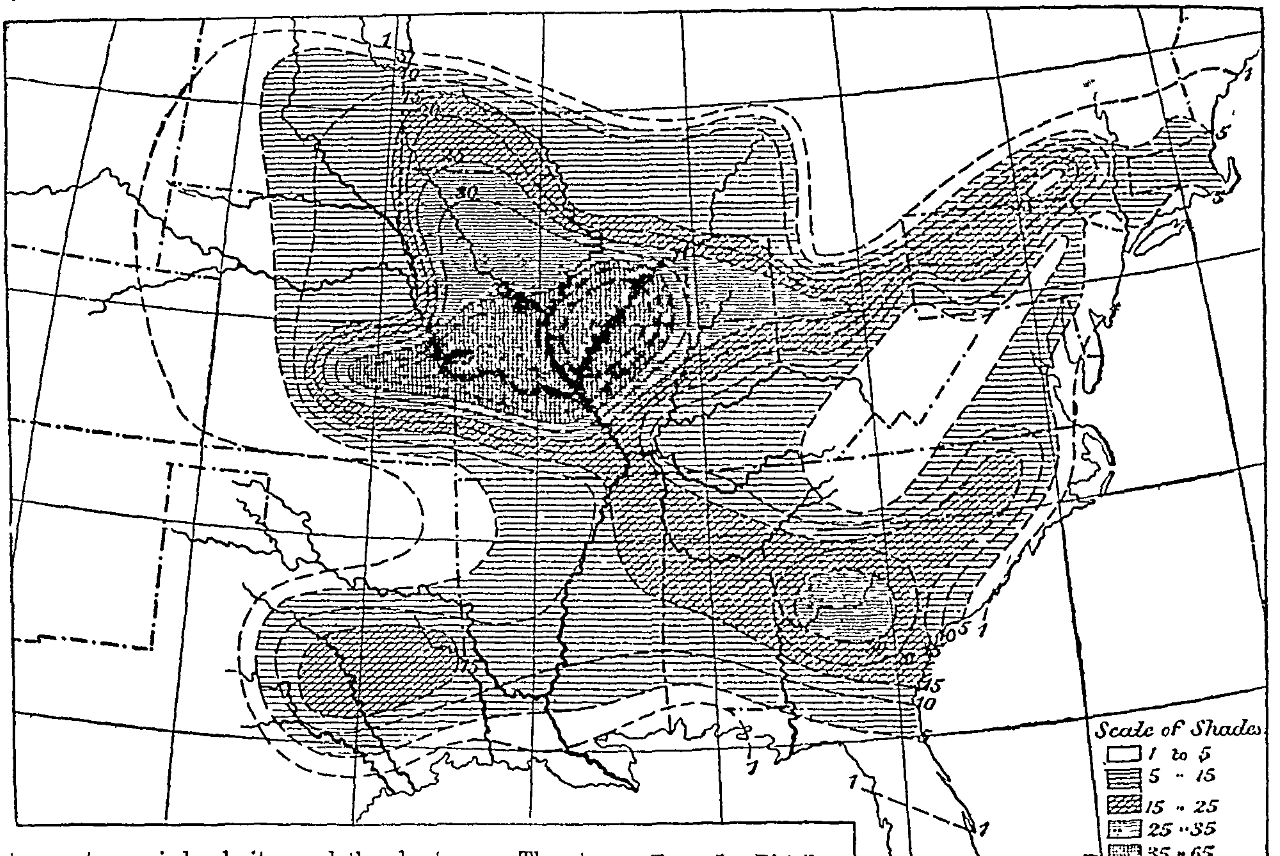

FIG. 5.—Distribution of Tornadoes in the United States.

Fig. 6 shows the waterspout in different aspects. A black cloud covers the sky, from which a projection is let down in the form of an inverted cone, as at A, which continues to increase and extend downwards. The sea immediately beneath is soon thrown into violent agitation, showing that the whirling movement which began in the clouds has extended to the sea, and is doubtless continuous throughout, though the portion of the column from A downwards is not yet made apparent by the condensation of its contained vapour into cloud. As the whirling movement of the column becomes more intensely developed, the increased rapidity of the gyrations brings about increased rarefaction of the air within, with the inevitable result of increased condensation of the vapour into cloud downward. The protrusion of the cloud and its extension downwards are thus not due to the descent of vapour from the clouds, but to the visible condensation of the vapour of the spirally ascending air-currents arising from an increasing rarefaction due solely to the accelerated rate of the gyrations, the condensation being analogous to that of the cloud seen in exhausting an air-pump.

Under each of the columns of fig. 6 the surface of the sea is seen to be more or less heaped up, as well as in violent agitation, showing that atmospheric pressure immediately under the gyrating columns is less than it is all round. On land, when the tornado passes directly over a dwelling house or other closed building, it often happens that the whole building, walls and roof, is thrown outward with great violence, the wreckage presenting the appearance of a sudden explosion, proving that atmospheric pressure outside the building was instantaneously and largely reduced, and the building shattered to fragments by the expansion of the air within. It is in this way that the tornado does some of its most dreadful work.

The wind of the tornado reaches a velocity probably never equalled in cyclones. During the Ohio tornado of February 4, 1842, large buildings were lifted entire from their foundations, carried several rods through the air, and then dashed to pieces, some of the fragments being carried distances of 7 and 8 miles; and large oaks nearly 7 feet in girth were snapped across like reeds. This tornado swept on its course at the rate of 34 miles an hour, and at one

place did its fearful work in the brief space of a minute. The tornado which passed over Mount Carmel (Illinois), June 4, 1877, swept off the spire, vane, and gilded ball of the Methodist church, and carried it bodily 15 miles to north-eastward. The velocity of the ascending currents which kept this heavy object suspended in the air for 15 or 20 miles must have been very great.

Of the tornadoes the progressive courses of which were recorded, 310 advanced towards N.E., 38 towards S.E., 16 towards E.N.E., 14 towards E., 7 towards N.N.E., 5 towards E.S.E., and 3 towards S.S.E. The course is thus always towards some easterly direction, the great majority being towards the north-east. The velocity of their onward movement varied from 12 to 60 miles an hour, the average being 30 miles an hour. The time occupied in passing a particular spot varied from 10 seconds to half an hour, the mean time being nearly six minutes and a half. The width of the path of destruction marked with debris and other relics of the violence of the tornado varied from 40 to 10,000 feet, the average being 362 yards. The direction of the whirling movement of the tornado was invariably from right to left, or the opposite of the movement of the hands of a watch, resembling in this respect the vorticose movement of cyclones in the northern hemisphere. The passage of the tornado cloud is often described as accompanied with remarkable noises, which observers variously characterize as terrible, deafening, a terrific crash, the roar of a thousand trains of cars, or the uproarious din of innumerable pieces of machinery.

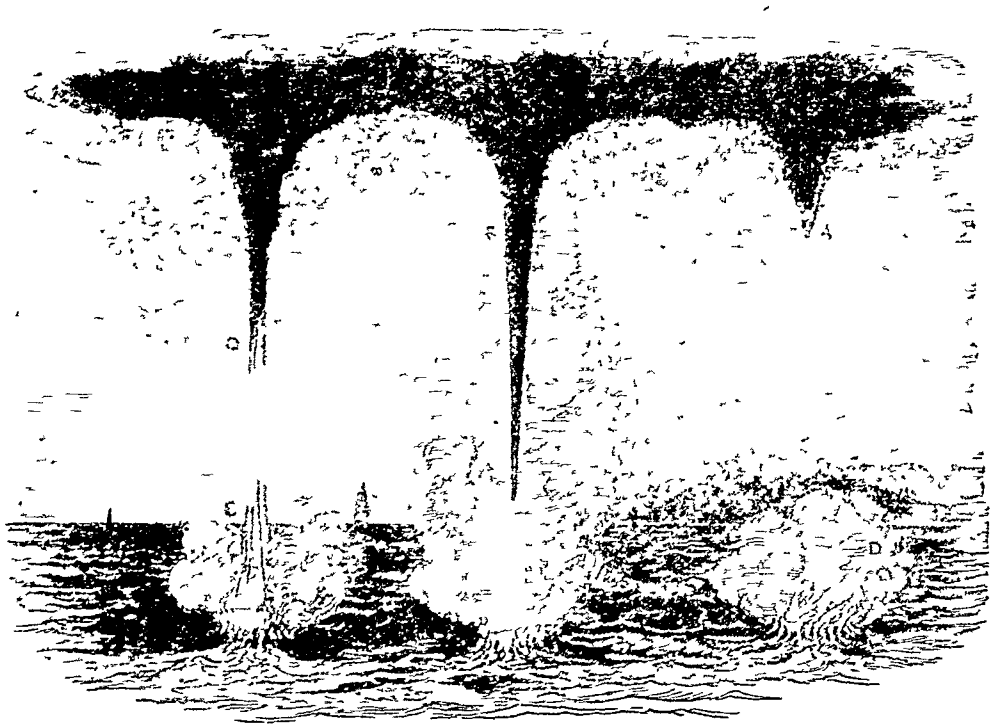

FIG. 6.—Forms of Waterspouts.

The usual position of the gyrating columns of cloud is vertical; but occasionally a curving form or slanting direction is assumed. It is probable that to these latter forms many stationary or slowly moving dangerous squalls are to be referred, which spring up with unexpected suddenness in lakes and arms of the sea in mountainous regions.

The dust storm of India, Arabia, and Africa is a well-marked type of the whirlwind. Previous to the outbreak of a dust storm the air is unusually calm and sultry, just as happens in the case of the tornado. The simplest form of the dust storm is that of a tall aerial column of sand moving onwards, and drawing into itself, as it whirls round in its course, dust and other light bodies within the sweep of the strong air-currents which blow along the surface of the ground and converge vorticosely round the base of the column. A form commonly seen is shown in fig. 7, which represents several dust columns grouped together, each whirling independently round its own axis with incurving air-currents at the base, while the whole group of columns is borne bodily forward, and presents striking aspects as the forms and relative positions of the columns are changed. The importance of the observations made on dust storms as leading to a correct understanding of the whirlwind consists in this that it affords conclusive evidence that there is a strong inflow of the air along the surface of the ground all round vorticosely towards the base of the whirlwind, and that these same inflowing air-currents afterwards ascend through the air along the central axis of the whirlwind, carrying with them the evidence of their ascent in the visible solid particles of dust, sand, and other light objects they whirl up with them in their ascending course.

Owing to the extreme dryness of the air-currents involved in the dust storm, the rarefaction generated by the rapidity of the gyrations is insufficient to produce condensation of the aqueous vapour in the interior of the column. Quite different, however, is it with waterspouts and tornadoes, where, in the great majority of cases, the air near the surface before being drawn into the ascending vortex is of a high temperature and near the point of saturation. From the extreme rarefaction to which these air-currents are subjected, owing to their sudden ascent in a rapidly gyrating column, excessive condensation follows, with an aqueous precipitation at times so astonishing that it can only be fittingly described as an aerial torrent of solid water, or an aerial avalanche of hail and ice.

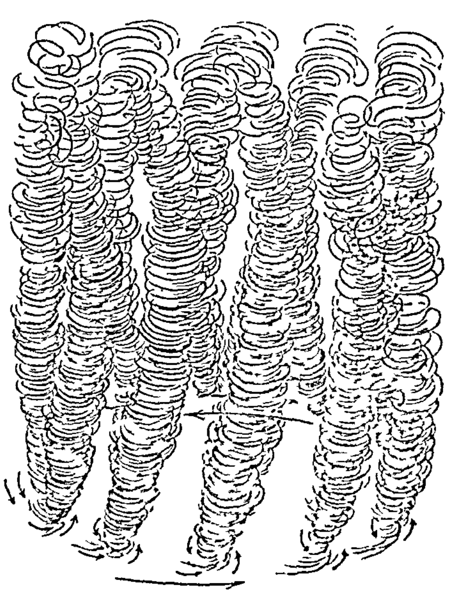

FIG 7.—Dust Storm.

Certain tracts of the ocean included within what may be called permanent anticyclones, or where atmospheric pressure is higher than all round, are characterized by an absence or comparative absence of rain. These regions are also remarkable for clear skies and strong sun heat. Similarly small anticyclonic areas occurring between or in the vicinity of cyclones are characterized by dry air and clear skies, and it is under these conditions that the strongest sun heat is felt. When, as repeatedly

happens in the warmer months of the year, anticyclones remain practically stationary for some time, the lowermost strata of the air become abnormally heated,—thus bringing about a vertical disturbance of the equilibrium of the atmosphere out of which whirlwinds originate. It is under these conditions that white squalls or fair-weather whirlwinds occur, the originating cause of this special form being the great dryness of the air due to its place in the anticyclone, and the abnormally rapid diminution of temperature and humidity with height owing to the strong insolation through the clear dry atmosphere. The clouds accompanying the white squalls are at a great height, but the commotion and boiling of the sea under them and following them as they drift onwards show that the squalls are true whirlwinds, the vapour column of the waterspout not being formed solely on account of the extreme dryness of the air which ascends the columns. The white squall accompanies fine weather, and its appearance is sudden, its duration brief, and its destructive power at times so dreadful that it has been known to strip a ship of every sail and mast in a few seconds, and leave it rolling a helpless log amidst the tremendous sea which follows it. In sailing through such regions a close lookout should be made, particularly when the weather looks singularly fine, the skies beautifully clear, the air calm or nearly so, and the temperature and moisture of the air on board the vessel noticeably high.

Diurnal Period of Hail.—The hail here referred to is round, hard, and compact, and in the form of clear or granular ice, the hailstones sometimes being found when broken across to be composed of alternate layers of these two states of ice. The following figures show the number of times it has occurred during the different hours of the day at Coimbra during the last six years:—

Midt. to 2 A.M.	0	8 A.M. to 10 A.M.	3	4 P.M. to 6 P.M.	3
2 A.M. ,, 4 ,,	1	10 ,, ,, Noon	20	6 ,, ,, 8 ,,	1
4 ,, ,, 6 ,,	2	Noon ,, 2 P.M.	15	8 ,, ,, 10 ,,	0
6 ,, ,, 8 ,,	1	2 P.M. ,, 4 ,,	13	10 ,, ,, Midt.	0

A diurnal period is thus well-marked at Coimbra, where forty-eight out of the fifty-nine cases have occurred from 10 A.M. to 4 P.M. This period is essentially the same as those calculated for a large number of places in representative climates, care having been taken to limit the inquiry to the particular hail described above. The important point to be noticed in the diurnal period of hail is that the time of maximum is about two hours earlier than the maximum period of thunderstorms. The maximum period for the thunderstorm is when the ascending current from the heated land is at its greatest force for the day; but the maximum period for hail is some time before the ascending current has fully established itself, or at that time of the day when the vertical disturbance of the atmosphere is greatest,—in other words, when atmospheric temperature and vapour fall with height at a much greater rate than the normal. In the higher latitudes hail falls almost exclusively during the warmer months of the year. In regions where the summer climate is practically rainless no hail falls; and where the rainfall is small and at distant intervals few cases of hail occur. Thus at Coimbra, where little rain falls in summer, hail was recorded as having fallen only once in the six years during the four dry hot months from June to September.

All hail is probably connected immediately with whirlwinds, more or less developed; and it is when the hailstorm is one of the phenomena attendant on the tornado or on a great thunderstorm that it assumes its most destructive form. The theory of the formation of hail has been stated by Ferrel in his *Meteorological Researches for the Use of the Coast Pilot*, part ii. p. 85. The vapour carried aloft by the gyrations of the tornado is below a certain height condensed into cloud and rain, but above that height into snow. Let the raindrops formed below be carried up into the snow region by the powerful ascending currents of the tornado and be kept suspended there a little while, and they become frozen into hail. If now these be thrown quite outside the gyrations of the tornado, they fall to the earth as a shower of compact homogeneous hailstones of clear ice of ordinary size. If, however, they are caught in the descent and carried in toward the vortex by the inflowing currents on all sides, they are again rapidly carried aloft into the freezing region. A number of such revolutions of ascent and descent may be made before they fall to the earth. While high up in the snow region, the hailstones receive a coating of snow; but, while traversing the region lower down where rain yet unfrozen is carried up, they receive a coating of solid ice. Thus alternate coatings of snow and ice are received, and the number of each sort indicates the number of revolutions described before the hailstones fell to the ground. When the nucleus is composed of compact snow, as is generally the case, the hailstone had its origin high up in the snow region as a small ball of snow, or soft hail (*Graupel* in German and *grésil* in French); but when it is composed of clear ice throughout it was formed in the rain region, carried up into the snow-region and there frozen, and immediately afterwards fell to the ground.

Monthly, Annual, and Irregularly Recurring Phenomena.

The Temperature of the Sea.—Figs. 8 and 9, representing the distribution of the temperature of the surface water of the ocean for the two extreme months February and August, are reproduced chiefly from *The Wind and Current Charts for Pacific, Atlantic, and Indian Oceans*, published by the British Admiralty in 1872.

In February (fig. 8) the temperature of the surface of the sea falls to the annual minimum over the northern hemisphere, and rises to the maximum in the southern hemisphere. The course of the isothermals more closely follows the latitudes in the Pacific, Indian, and South Atlantic Oceans; but the divergence from the latitudes is great and striking over the North Atlantic. The wider and more open the ocean the more does the distribution of the temperature approach the normal; and the more confined the ocean the greater is the divergence from the normal. The key to the anomalous distribution of the temperature of the ocean is furnished by the charts of the distribution of atmospheric pressure and the prevailing winds of the globe. So far as observation has gone it would appear that the surface currents are practically altogether caused by the prevailing winds over the respective oceans, subject to such deflexions in their courses as are occasioned by the land.

In the southern hemisphere the currents on the west side of the Indian Ocean flow southwards along the east coast of Africa, and, since the currents here pass from lower to higher latitudes, the temperature along the whole extent of this coast is raised considerably above the normal. On the other hand, since the currents on the west coast of Africa flow from south to north—in other words, from higher to lower latitudes—the ocean currents which impinge on this coast have a temperature much under the normal. The winds and currents on the coasts of South America are precisely analogous to those of Africa, and the distribution of the temperature of the sea is also similar. The temperature of the ocean on the east coast of that continent is for the same latitudes everywhere higher than on the west coast. Even in the smaller continent of Australia the same law holds good.

In the northern hemisphere a different distribution of the temperature of the sea is seen at this season. In the Atlantic the temperature is very much higher on the west of Europe than on the east of America. On the east of America from Wilmington to Boston occur the most rapid transitions in the mean temperature of the ocean anywhere on the globe, the temperature falling in that short distance from 70° to 30°, whereas on the eastern side of the Atlantic these isothermals pass Cape Verd Islands and Spitzbergen respectively. In the winter months the prevailing winds of the east side of North America are north-westerly, whilst in the central and eastern portion of the Atlantic they are south-westerly, thus pouring along the east coast of America the icy currents of the Arctic regions, but over the central Atlantic and along the western shores of Europe the warm waters of southern climates. The

easterly and south-easterly winds of Scandinavia in winter lower the isothermals along these coasts. A striking feature of the winter isothermals of the Atlantic is the singularly high temperature along the centre stretching from Spitzbergen towards the south-west and extending in a modified degree as far south as the West Indies. In the Pacific this feature of the mid-ocean temperature is much less pronounced, and the excess of temperature on the west of America over what occurs in the same latitudes of eastern Asia is not so great as the difference observable between the two sides of the Atlantic.

The highest mean temperature in February (85°) occurs in the Indian Ocean to the south-west of Sumatra, and there is a patch the

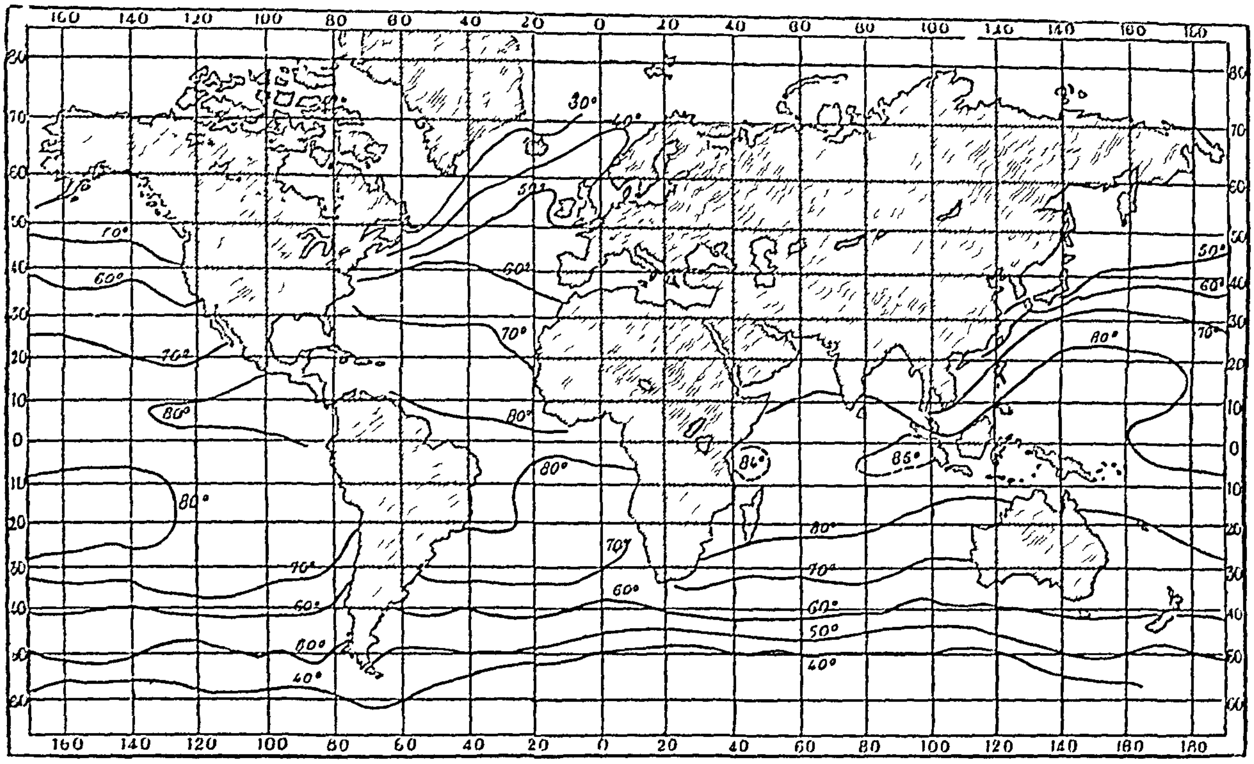

Fig. 8.—Isothermals of the Surface of the Sea for February.

temperature of which is 84° to the north of Madagascar. The highest means in the Atlantic are 82° in the north-east angle of the Gulf of Guinea, and 81° off the north east coast of Brazil. In the Pacific the highest are 83° to the north of the Fiji Islands and 81° near the Marshall Islands.

In August (fig. 9) the southern half of the Red Sea shows a mean temperature of 90°, being the highest mean recorded for the ocean anywhere at any season. Patches showing a summer mean of 85° occur in the Chinese Sea to the east of Tonquin, in the Bay of Bengal to the east of southern India, about Socotra, and to the

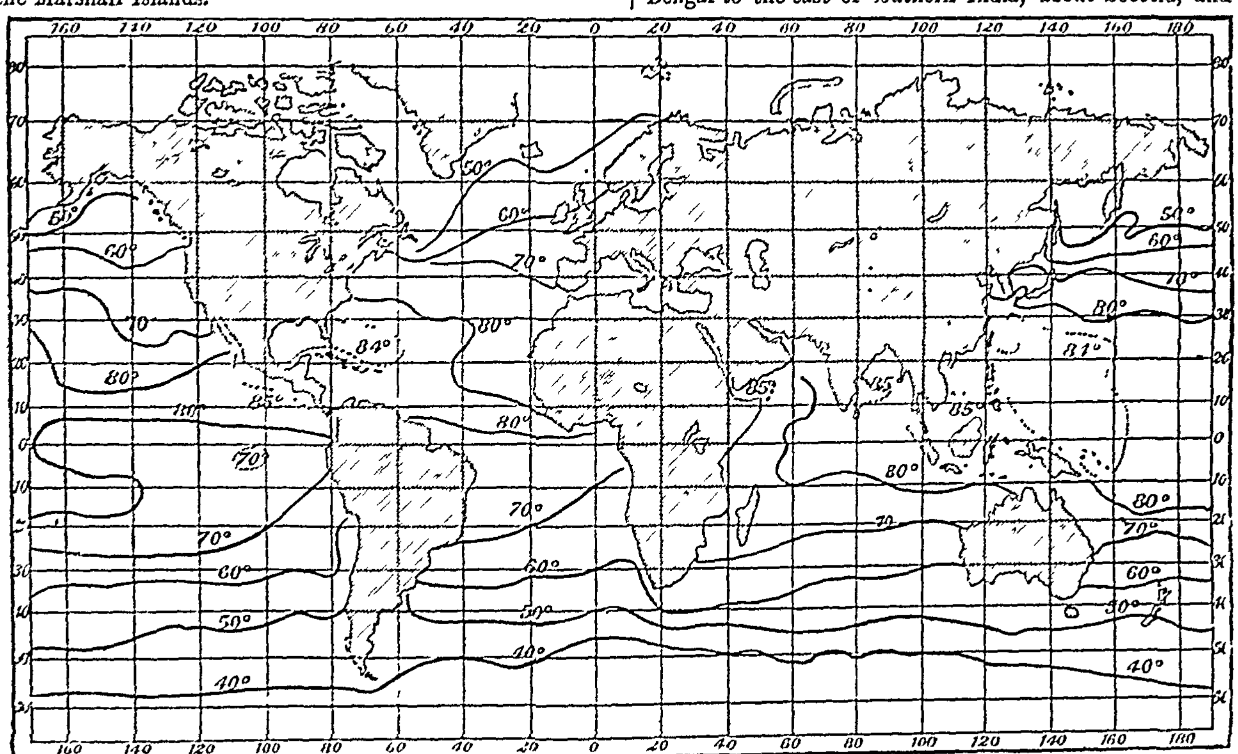

Fig. 9.—Isothermals of the Surface of the Sea for August.

west of Central America. But the most extensive regions of high temperature are in the west of the Pacific between long. 165° E. and the Philippines northward nearly to Japan and southward to New Guinea, and the Gulf of Mexico and the adjoining part of the Atlantic as far east as long. 57° W. A patch of remarkably low temperature occurs in the Pacific a little to the west of Galapagos, where the mean is only 70°, being 10° lower than what occurs anywhere else near the equator at this season.

The influence of currents is strongly expressed in the temperature of all the oceans. In the south of Asia the monsoons are S.W., S., and S.E. Under the impulse of these monsoonal winds an extensive surface drift of the waters of the equatorial regions is

carried northwards towards southern Asia, and consequently very high temperatures characterize these seas in summer. It is instructive to note the effect on the temperature of the sea resulting from the region of high atmospheric pressure in the North Atlantic at this season. Out of this anticyclonic region the winds blow in all directions, giving rise to surface currents flowing in the same directions. Thus to the west of Africa the winds and currents are from north to south; and hence the temperature of this part of the ocean is abnormally reduced. On the other hand, on the west side of this high pressure area, the prevailing winds and currents are from south to north; and it will be seen that the temperature of the whole of the region swept by the southerly winds is abnormally raised. On the north side of the area, the winds and currents are westerly as far as about long. 35° W., and over that space the isothermals follow the parallels of latitude. Farther to eastward and northward the prevailing winds become south-westerly, thus propelling northwards along the western shores of Europe, by oceanic surface drifts, the warmer waters of southern latitudes. Meanwhile the currents of cold water and ice drifts from the Arctic regions keep the temperature off America to the north of Newfoundland at a figure considerably lower than is observed in any other region in the same latitudes. In August similar relations exist as in January between the east and west coasts respectively of South Africa, South America, and Australia, all of which are readily explained by the charts of mean atmospheric pressure and the resulting prevalent winds.

One of the most striking facts of ocean temperature is that the temperature of the Southern Ocean from about 50° to 60° S. lat. is practically the same in January and August, a circumstance due chiefly to the magnificent icebergs of that ocean.

The Temperature of the Land.—In regions where the rainfall is distributed through all the months of the year, and where snow covers the ground for only a small part of the year, the mean temperature of the soil nearly equals that of the air. But when the year is divided into wet and dry seasons, and when snow lies during a considerable portion of the year, the mean annual temperature of the soil may be above or below that of the air. The greatest difference between the temperature of the soil and that of the air occurs where the surface of the ground is covered during several months with snow. Snow is a bad conductor of heat, and thus obstructs the free propagation of the cold produced by radiation downwards into the soil, and the escape of heat from the soil into the air. In this way, over a considerable portion of the Russian empire, the temperature of the soil is considerably in excess of that of the air. Thus at a place 120 miles south of Archangel the temperature of the soil is 10° higher than that of the air; and at Semipalatinsk it is 9° higher.

The daily changes of temperature only affect the soil to depths of about 4 feet. The precise depth varies with the degree of the sun-heat and with the nature of the soil. Similarly the heat of summer and the cold of winter give rise to a larger annual wave of heat propagated downwards, the amplitude of which diminishes with the depth till it ceases to be perceptible. Principal Forbes showed from observations on the Calton Hill, Edinburgh, that the annual variation is not appreciable lower than 40 feet below the surface, and that under 25 feet the change of temperature through the year is small. The depth at which the annual variation ceases, or where the temperature remains constant, is a variable depending on the conductivity and specific heat of the soil or rock, but particularly on the difference between the summer and winter temperatures. The rate at which the annual wave of temperature is propagated downwards is so slow that at Edinburgh, at a depth of 24 feet, the highest annual temperature does not occur till January 4, and the lowest till about July 13, thus reversing the seasons at this depth. At Greenwich, at a depth of 25½ feet, these phases of the annual temperature occur on November 30 and June 1.

Professor Everett in the *Report of the British Association* for 1879 has summarized the results of the observations of underground temperature. The temperature of the surface of the ground is not sensibly influenced by the flow of heat from below upwards, but is determined by atmospheric and astronomical conditions. The temperature gradient is defined as the rate of increase of the temperature downwards, and it may be taken as averaging one degree Fahrenheit for every 50 or 60 feet, the exact rate in particular cases being very variable. Thus the temperature gradient of the soil is about five times steeper than the temperature gradient of the air. The temperature gradient is steepest beneath gorges and least steep beneath ridges; and hence the underground annual isothermals are flatter than the uneven surfaces above them. This is the case even with the uppermost isothermal of the soil, and the flattening increases as we pass downwards until at a considerable depth they become horizontal. Where the surface of the ground and the isothermal surfaces beneath it are horizontal, the flow of heat is vertical, and the same quantity of heat flows across all sections which lie in the same vertical. In this case the flow across a horizontal area of unit size is equal to the product of the temperature gradient by the conductivity, if the latter term be used in an extended sense, so that it includes convection by the percolation of water, as well as conduction proper; and hence, in comparing different strata in the same vertical, the gradient varies in the inverse ratio of the conductivity.

Since the effects of the cold generated by nocturnal radiation mostly accumulate on the surface of the earth, but the effects of solar radiation are spread to some height by ascending currents from the heated ground, it might be expected that the annual temperature of the surface layer of the soil would be lower than that of the air resting over them. Observations prove that such is the case. Springs which have their sources at greater depths than that to which the annual variation penetrates have a constant temperature throughout the year, and if they do come from a depth considerably greater than this they may be regarded as giving a very close approximation to the mean annual temperature of the place. The temperature of cellars is also very near the mean annual temperature of the locality; at any rate this temperature may be secured for cellars anywhere.

Distribution of Temperature in the Atmosphere.—Of the larger problems of meteorology, the distribution of temperature in the atmosphere over the land surfaces of the globe was the first that received an approximate solution (by Humboldt). But as regards the ocean, which comprises three-fourths of the earth's surface, the question of the monthly and annual distribution of temperature in the atmosphere over it can scarcely yet be said to have been seriously looked at. The isothermals of the temperature of the atmosphere which cross the oceans continue still to be drawn essentially from observations made on the islands and along the coasts of these oceans. The first step towards the solution of this vital problem in climatology and other branches of meteorology is the construction of charts of mean monthly temperature of the surface water of the sea over all parts of the ocean from which observations for the purpose are available. In prosecuting this line of inquiry, excellent work has been done by the Meteorological Office as regards parts of the Atlantic between the tropics and the ocean to the south of Africa, and also by the Dutch, French, and German meteorologists. With such charts it would not be difficult, by a careful comparison during the same intervals of time between the temperature of the surface of the sea and that of the air resting over it, to construct monthly charts of the temperature of the atmosphere over the oceans of the globe.

In this connexion the whole of the observations of the temperatures of the air and sea made on board the "Challenger" have been examined, and sorted into one hundred and seventy-four groups according to geographical position, and the differences entered on a chart of the route of the expedition. In the Southern Ocean between latitudes 45° and 60° the temperature of the sea was lower than that of the air, the mean difference being 1°·4. The temperature of the air is here higher owing to the prevailing W.N.W. winds, and that of the sea lower owing to the numerous icebergs. To south of lat. 60° S. the sea was nearly 2°·0 warmer than the air, the result in this case being due to the open sea, which keeps up a higher surface temperature, and to an increased prevalence in these higher latitudes of southerly winds, thus lowering the temperature of the air.

The period during which the temperature of the sea exceeded that of the air was from June 1874 to March 1875, or during that part of the cruise from Sydney to New Zealand, and through the East India Islands to Hong Kong and thence to the Admiralty Islands. During the whole of this time, except when passing the north of Australia, the sea was much warmer than the air, the

general excess being from 2° to 3°, rising even near Tongatabu to upwards of 4°. The climate of the southern part of this extensive region at the seasons visited has a large rainfall, much cloud, and consequently a comparatively small evaporation and sunshine. In June, when the "Challenger" passed the north of Australia, the climate was very dry, the sunshine strong, and the evaporation large, and there the sea was slightly colder than the air. In the Atlantic between lat. 20° N. and 20° S. the sea was everywhere warmer, the mean excess being about a degree; and in the Pacific between lat. 30° N. and 30° S. the sea was also warmer, the mean excess being a degree and a half.

On the other hand, in the Atlantic from lat. 40° to 20° N. the sea was, on the mean, half a degree colder than the air. This region is remarkable for the high pressure which overspreads it, for the winds and currents which flow out in all directions, for its clear skies, strong sunshine, and consequently large evaporation, by which the temperature of the surface of the sea is lowered, and that of the air resting on it, being open to the heating influence of the sun, is raised. Similarly in the North Pacific from lat. 40° to 30° the temperature of the surface of the sea was half a degree lower than that of the air.

These remarks apply only to the observations made strictly on the open sea. Near land very great differences were observed which varied with season. Thus at Hong Kong during the latter half of November 1874 the sea was 3°·7 warmer than the air, the low temperature of the air at this season being caused by the lower temperature of the land and the northerly winds which then prevail; on the other hand, at Valparaiso in November and December of the following year the sea was 5°·8 colder than the air during the three weeks the "Challenger" was there, the difference being due to the cold oceanic current which sweeps northwards past that coast, and the rapid increase in the temperature of the air at that time of the year. These results will help us in gaining some knowledge of the temperature of the air over the oceans of the globe in February and August, taken in connexion with a careful examination of the sea temperature of these months represented in figs. 8 and 9.

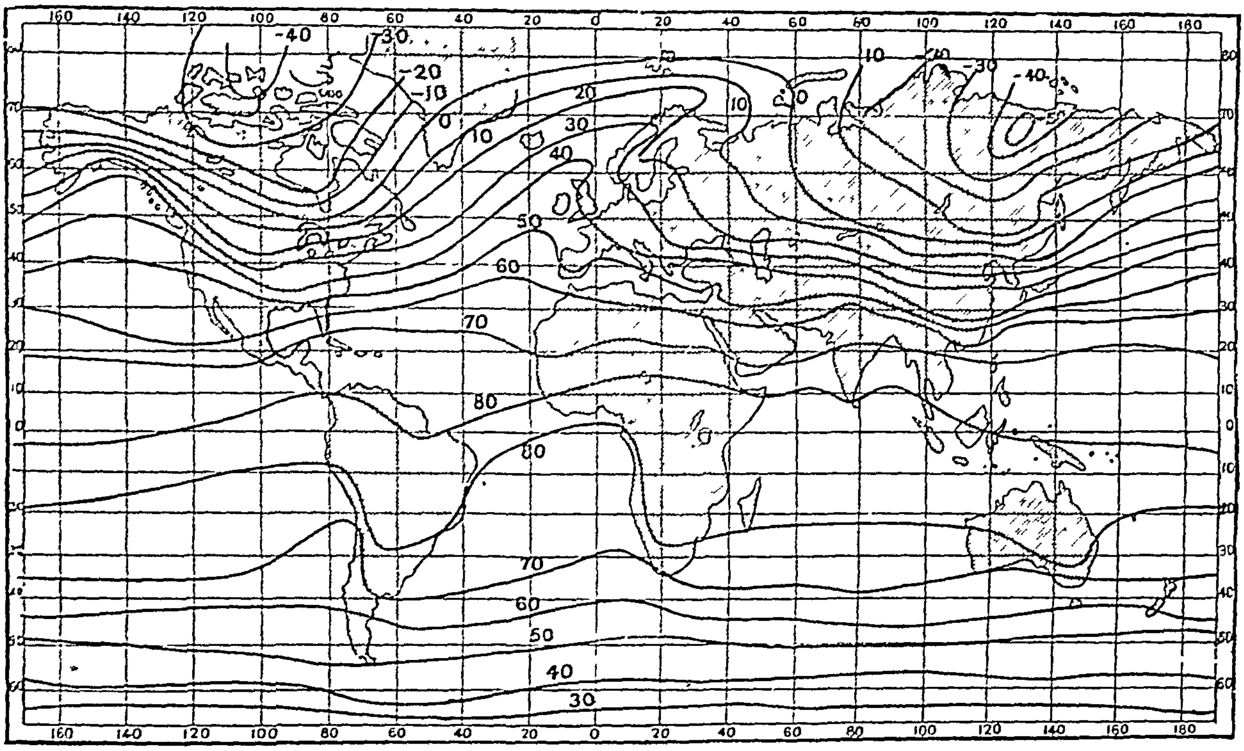

Fig. 10.—January Isothermals of the Surface of the Globe.

The distribution of temperature over the surface of the globe is shown by figs. 10 and 11, which represent the temperature of the two extreme months January and July for the eleven years 1870 to 1880. The region of highest temperature, which may be regarded as comprised between the north and south isothermals of 80°, forms an irregularly shaped zone, lying in tropical and partly in subtropical countries. On each side of this warm zone the temperature diminishes towards the poles, and the lines showing successively the gradual lowering of the temperature are, roughly speaking, arranged parallel to the equator, thus showing in an unmistakable manner the predominating influence of the sun as the source of terrestrial heat. While this decrease of temperature corresponds in a general way to what may be called the solar climate, there are great deviations brought about by disturbing causes.

Among these disturbing causes the unequal distribution of land and water holds a prominent place. In January the earth presents to the perpendicular rays of the sun the most uniform surface, or the largest water surface, and in July the most diversified surface, or the greatest extent of land. Hence the zone of the earth's surface comprised between the isothermals of 80° is less irregular, and also spreads over an area more restricted, in January than in July. In July the areas enclosed by the isothermals of 80° and 90° are much larger in the Old World than in the New, it being the former which presents the larger land surface to the perpendicular rays of the sun; and in January, the summer of the southern hemisphere, the most extensive area of high temperature occurs in Africa and the least in Australia, the high-temperature area of South America being intermediate. In contrast to this the belt of temperature exceeding 80° is of least breadth where it crosses the Pacific and Atlantic Oceans, the absolute minimum breadth being in July in the Pacific, the largest ocean, where the disturbing influence of the land is least.

During the cold months of the year, when the sun's heat is least and the effects of terrestrial radiation attain the maximum, the greatest cold is over the largest land surfaces which slant most to the sun. Thus the lowest mean temperature that occurs anywhere or at any season on the globe is −55°·8 at Werchojansk (lat. 67° 34′ N., long. 133° 51′ E.) in north-eastern Siberia. In Arctic America the lowest isothermal is −40°·0. During the winter the ocean everywhere maintains a higher temperature in all regions open to its influence, as is seen, not only in the higher latitudes to which the isothermals push their way as they cross the Atlantic and Pacific, but also in their irregular courses over and near the Mediterranean, Black, Caspian, and Baltic Seas, Hudson's Bay, the mouth of the St Lawrence, the American lakes, and all other large sheets of salt and fresh water. The disturbing influence of sheets of water on the temperature in all seasons is very strikingly shown when the isothermals are drawn for every

degree, these marking out the prominent features of local climates, a knowledge of which is of so great importance to the agriculturist, the horticulturist, and the invalid. Figs. 12 and 13 represent charts of temperature of this description for the British Islands for 1870–1880 from the *Jour. of Scot. Meteor. Soc.*, vol. vi. In the winter of the

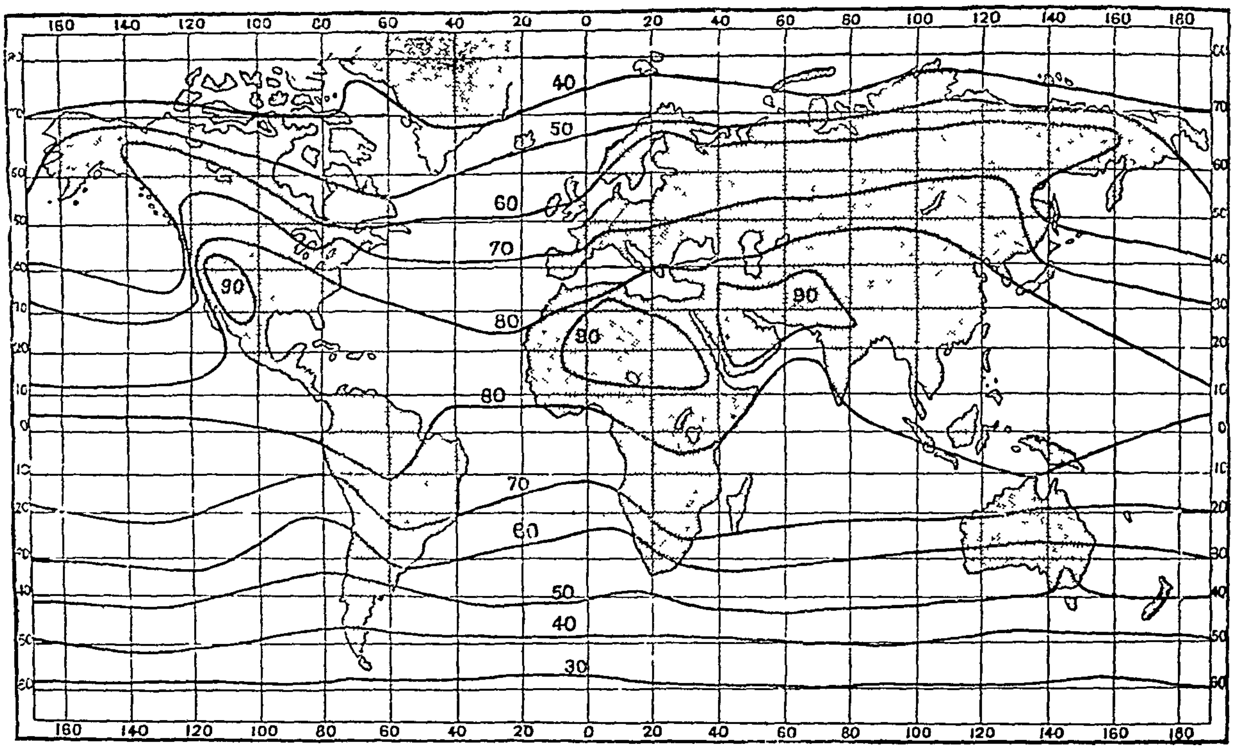

FIG. 11.—July Isothermals of the Surface of the Globe.

southern hemisphere the depressing influence of the land on the temperature is but slightly felt, owing to the small

FIG. 12.—Mean Temperature of the British Islands in January.

extent of the land surfaces and the comparatively low latitudes to which they extend southwards. In the south-east of Australia and in the basin of the La Plata, a lower temperature prevails in the interior.

Another prominent disturbing cause operating on the

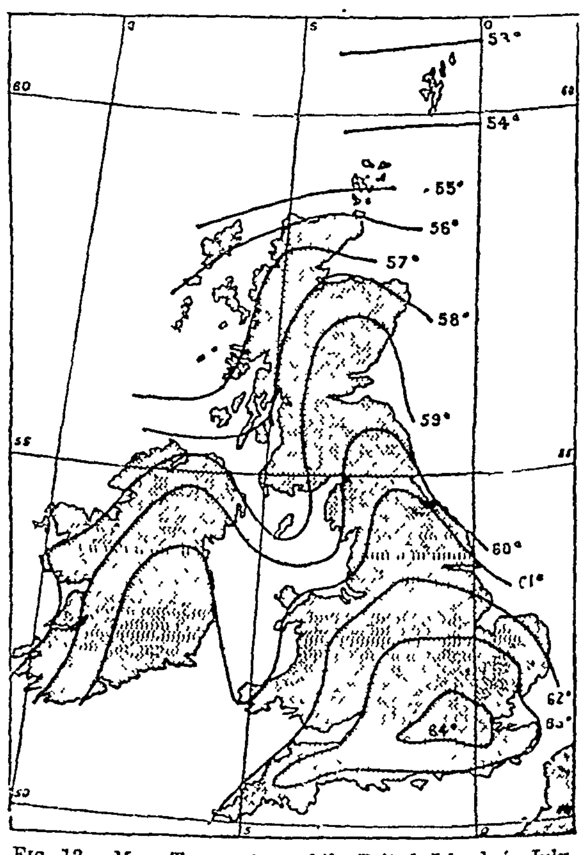

FIG. 13.—Mean Temperature of the British Islands in July.

mean temperature is to be found in the seasonal areas of low and high mean pressure in their connexion with the prevailing winds. Of these the most marked is the system of

narrow limits, as regards their temperature. The deflexions of the isothermals near the Baltic, Mediterranean, Black, and Caspian Seas and the freshwater lakes of America all point to the disturbing influence of these sheets of water on the temperature.

The height and direction of mountain ranges is an important element in determining climate. If the ranges are perpendicular to the prevailing winds and of a considerable height, they drain the winds of much of their moisture, thus causing to places to leeward colder winters and hotter summers, by partially removing their protecting screen of vapour, and exposing them more completely to solar and terrestrial radiation. Of this Norway and Sweden and the British Islands form excellent illustrations. It is this that makes the most important distinctions among climates in regions near each other, as respects both animal and vegetable life. With regard to the decrease of temperature with height, very much yet remains to be done before an approximation to the law of decrease can be stated. During the five months observations were made on Ben Nevis in the summer of 1881 the difference between the mean temperature at sea-level adjoining and at the top of the Ben, 4406 feet above the sea, was 15°·7, which shows a mean decrease of 1° Fahr. for every 280 feet of elevation. The actual differences from day to day varied from 1°·4 to 23°·2. As Ben Nevis forms a peak, and is in the very middle of the strong winds from the Atlantic, it is highly probable that this rate of decrease is a close approximation to the true decrease of the temperature of the air during the summer months in that part of the British Islands. When observations are made on elevated plateaus of some extent, the rate of decrease deduced from the observations will be less than the true rate in the free atmosphere in summer and greater in winter. The rate is thus a variable quantity, varying with latitude, situation, dampness or dryness of the air, calm or windy weather, and particularly with the season of the year. One degree Fahrenheit for every 300 is the rate of decrease generally assumed.

Amount of Aqueous Vapour.—It is scarcely possible to overestimate the importance of a knowledge of the horizontal and vertical distribution in the atmosphere of its aqueous vapour, for it may be truly said that it forms one of the prime factors in all the larger problems of atmospheric physics. A first rough approximation to the geographical distribution of the vapour of the atmosphere was published by Mohn in 1875 in his *Grundzüge der Meteorologie*, p. 84, in which vapour-pressure curves are drawn for the globe for January and July. These leave much still to be done, not only in a further discussion of observations already made, but also in improvement of the methods of observation and in the tables for their reduction. The chief point of interest in Mohn's vapour curves is their striking resemblance to the isothermals of the same months, and they also suggest that this line of inquiry is yet destined to make large contributions to our knowledge of the unceasing changes which occur in the pressure, temperature, cloud, rain, and movements of the atmosphere.

Still less is known of the vertical distribution of aqueous vapour. It decreases, like temperature, with the height, and if the statement generally made be at all correct, that half of the whole vapour of the atmosphere is contained in the lowest 6000 feet, and that at 20,000 feet high there is only about a tenth of what is at the earth's surface, the rate of decrease with height proceeds at a greatly more rapid rate than is consistent with the supposition that it forms an independent vapour atmosphere existing under its own pressure. The establishment of an increased number of high-level stations, and a more systematic inquiry than has yet been attempted into the upper currents of the atmosphere, are much needed in the further development of this branch of meteorology. In carrying out the inquiry, invaluable assistance will be obtained from observations of the diurnal range of the barometer and from well-devised methods of observing the effects of solar radiation at the earth's surface.

Amount of Cloud.—In Scotland, which lies completely within the region swept by the south-westerly winds from the Atlantic, and presents a well-defined mountain range lying across the track of these winds, the clouds have a distinct annual period. In the west, at places quite open to these westerly breezes, the amounts of cloud in spring, summer, autumn, and winter are respectively 67, 69, 71, and 74, and the annual mean 70.[1] In the east, in such districts as East and Mid Lothian, which have extensive ranges of hills between them and the Atlantic, the proportions are 59, 63, 62, and 60, and the annual mean 61. Thus about a tenth more of the sky is covered with cloud at the western as compared with the eastern situations, and the distribution of cloud differs materially in western and eastern climates. In the west winter is the cloudiest season, but in the east it is summer, and these are respectively the months when most rain falls in the several climates. Everywhere spring is the season when the sky is clearest. In England, owing to the protection afforded by Ireland and Wales to the west and the comparative absence of ranges of hills, the amount of cloud is less than in Scotland, and it is more equally distributed over the country. The minimum amount occurs in spring, and the maximum in winter and autumn.

Some of the best illustrations of the seasonal variation in the distribution of cloud are afforded by the Old Continent. These variations are the simple consequence of the systems of wind caused by the high winter and low summer pressures of that continent. In eastern Siberia the prevailing winds in winter are N.W. or continental, and in summer S.E. or oceanic; and accordingly at Ajan, Nertchinsk, and Blagoweshtchensk the mean amounts of cloud in these two seasons are 18 and 44. On the other hand, in western Siberia and eastern Europe the prevailing winds in winter are S.W., or from lower to higher latitudes, and in summer N.W., or from higher to lower latitudes. Kazan may be taken as fairly representing this extensive region, and there the amounts of cloud for the four seasons beginning with winter are 71, 48, 44, and 62. As the N.W. winds of summer rise over the Ural mountains in their course, condensation of the aqueous vapour is increased, and hence over this region the cloud in winter and summer is nearly the same, the mean amounts at Bogoslovsk, Ekaterinburg, and Zlatoust being respectively 53 and 52. At Tiflis and Kutais, situated on the high ground which lies between the Black Sea and the south of the Caspian Sea, the means for winter and summer are 53 and 55. On the eastern coast of the Black Sea the westerly winds of summer are accompanied with the annual maximum cloud, the winter and summer amounts at Redut-Kale being 59 and 69. In Central Siberia, to which the S.W. winds of winter do not extend, and to the north of latitude 55°, the amount of cloud is much diminished, and the cloudiness of summer is nearly the same as that of winter.

In India, in all regions which lie open to the summer monsoon, the minimum amount of cloud occurs during the winter and the maximum in summer,—the mean amounts being 19 and 74 at Calcutta, 16 and 86 at Bombay, 48 and 71 at Colombo, and 25 and 90 at Rangoon. At Trincomalee, on the east coast of Ceylon, and thus exposed to the rains of the N.E. monsoon of winter, and largely protected from the rains of the S.W. monsoon of summer, the amounts of cloud in these seasons are 52 and 59. At Darjiling (6912 feet) and Chakrata (7022 feet high), both on the Himalayas, whither the summer monsoon penetrates, the mean amounts are respectively 53 and 86, and 43 and 73. At Leh, in Kashmir, the amounts are 59 and 51, the excess being thus in winter. In the Punjab and to westwards, or those regions in southern Asia to which the summer monsoon does not extend, the cloud in winter is everywhere greater than in summer. Thus the amounts are 24 and 18 at Mooltan, 38 and 25 at Peshawar, 27 and 19 at Jacobabad, and at Quetta, in Baluchistan, 5500 feet high, 42 and 14. Similar relations as to cloud obtain in Australia and the other continents where high pressures rule in the interior during

[1] In this section the amount of cloud is stated in percentages of the sky covered with cloud.

the cold months and low pressures during the warm months of the year. The maximum cloud occurs with winds from the sea and winds advancing into the colder regions of higher latitudes, and the minimum with winds which have traversed an extensive track of land and winds advancing into the warmer regions of lower latitudes. As the subject, however, is essentially one with rainfall, it is not necessary to prosecute it further.

The other atmospheric movements on which the amount of cloud depends are the ascending and descending currents of the atmosphere,—the ascending currents with clouded skies occurring in the belt of calms and over cyclonic areas and regions, and the descending currents with comparatively clear skies over anticyclonic regions. The region of maximum vapour and densest cloud-screen on the globe is the equatorial belt of calms between the trades, which has an annual movement northward and southward with the sun as already explained. To ascensional movements is to be ascribed part of the cloudiness of the southern and eastern sides of the winter cyclonic regions of the North Atlantic and North Pacific, and of the cyclonic regions of low summer pressure in the interior of Asia and other continents. On the other hand the comparatively small amount of cloud in the anticyclonic regions of the Atlantic and Pacific Oceans, and in the high-pressure regions of the interior of Asia and other continents during the cold months of the year, is due to the vast down-currents which occupy the centres of the anticyclones, and which become relatively drier as they descend owing to the increasing pressure to which the air is subjected.

Distribution of Atmospheric Pressure.—The importance of a knowledge of the distribution of atmospheric pressure, or of the mass of the atmosphere, over the globe in its varying amounts from month to month is self-evident. Observations teach us that winds are simply the movements of the atmosphere that set in from where there is a surplus towards where there is a deficiency of air; and observations also teach that isobaric maps (*i.e.*, maps showing the relative distribution of mean pressure) and maps showing the prevailing winds are in accordance with each other. Since prevailing winds to a large extent determine the temperature and rainfall of the regions they traverse, isobaric maps may be considered as furnishing the key to the more important questions of meteoro-

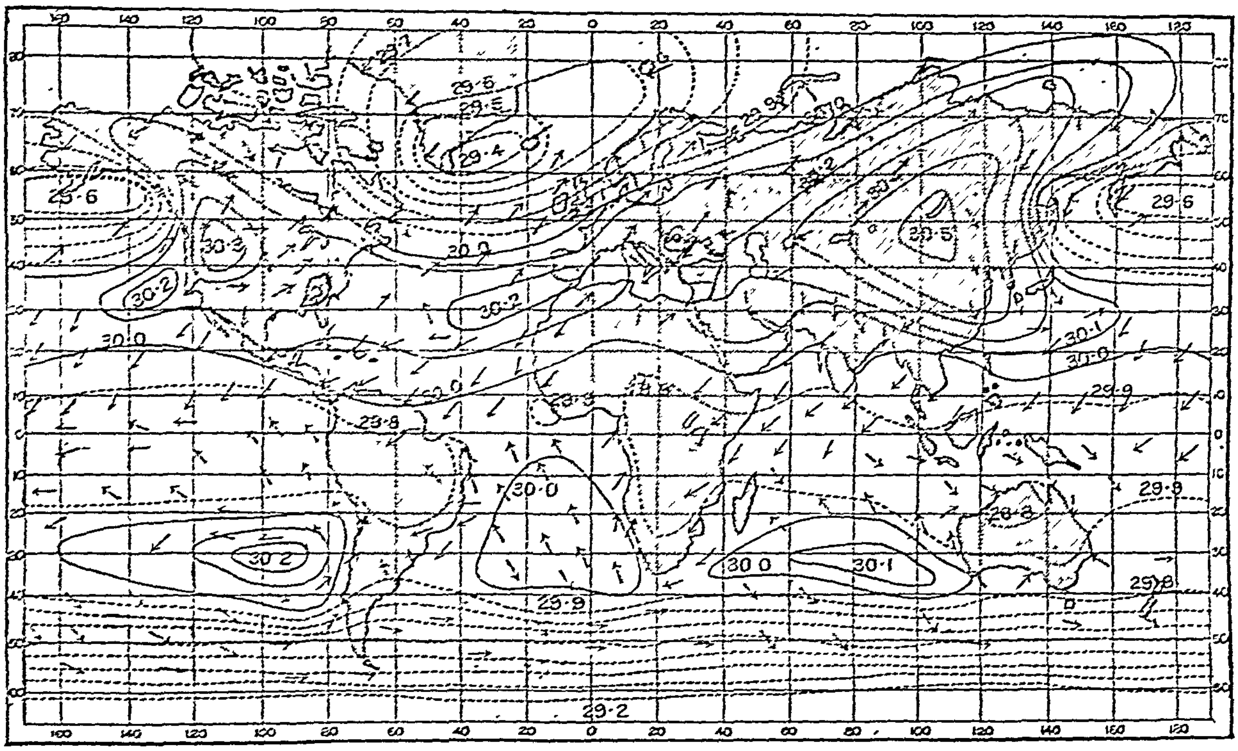

FIG. 14.—January Isobars of the Globe and Prevailing Winds.

logical inquiry. At the time of the first publication of isobaric maps of the globe in 1868, it was impossible to do more than present the subject in its broad general features, owing to the scantiness and quality of the materials then existing. But since then meteorological stations have been largely multiplied in all parts of the civilized world, and the general adoption of the issue of storm warnings has necessitated the use of more accurate barometers and uniform methods of observing. Since there is thus now the means of a more exact representation of this fundamental datum of meteorology, we have prepared a new set of isobaric maps, showing the distribution of the earth's atmosphere and the prevailing winds for January (fig. 14), July (fig. 17), and the year. They have been constructed from mean values calculated for the same eleven years (1870–80 inclusive) as the isothermal maps figs. 10 to 13, pressure of 30·0 inches and upwards being represented by solid lines, and of 29·9 inches and under by dotted lines, while the arrows show the directions of the prevailing winds at the localities indicated by the respective arrow-points.

Mean Atmospheric Pressure in January (fig. 14).—In this month, when the influence of the sun on the northern hemisphere falls to the minimum, the greatest pressures are massed over the continents of that hemisphere, and the least pressures over the northern parts of the Atlantic and Pacific Oceans, over the Antarctic Ocean and southern hemisphere generally. In the southern hemisphere there are three patches where pressure rises to 30 inches, viz., in the Atlantic between South America and Africa, south of the Indian Ocean, and in the Pacific between Australia and South America.

In the northern hemisphere, on the other hand, pressure rises in Central Asia to upwards of 30·5 inches, the mean pressure for January being at least 30·4 inches at Peking, Semipalatinsk, and Yenisei, and fully 30·5 inches at Irkutsk and Nertchinsk, in the upper basin of the Amur. This is the region where the normal atmospheric pressure attains to a maximum which is much higher than is reached in any other region or at any other time of the year. It will be observed that this region of highest pressure occupies a position near the centre of the largest continent. The area of high barometer is continued westward through Europe, through the horse latitudes of the Atlantic to Carolina, and thence through the United States to California, whence it crosses the Pacific to Asia. This belt of high pressure thus completely encircles the globe, broadening as it passes the land and contracting as it crosses the ocean. Its greatest breadth is over Asia and its least over the Pacific, or where land and ocean attain respectively their maximum dimensions.

Pressures greatly under the average cover the northern portions of the Pacific and Atlantic and also the greater part of the Arctic regions. In the north of the Pacific the normal pressure falls to about 29·6 inches between Kamchatka and Alaska. In the north of the Atlantic, however, a still lower mean pressure obtains over a narrow belt stretching from Iceland to the south of Greenland, the normal at Stykkisholm in the north-west of Iceland being 29·385 inches, and at Ivigtut in Greenland 29·361 inches. This low average for Ivigtut is the lowest normal known to occur anywhere and at any season in the northern hemisphere, and it is significant that the place is immediately to the north of that part of the Atlantic where a considerable number of the storms which sweep over Europe have their origin, and where not a few of the storms which cross the Atlantic from America develop intensity.

It has been seen that the highest mean pressure occurs near the centre of the largest extent of land; but as regards the two oceans the lowest pressure is met with in the northern division of the Atlantic, which is the lesser ocean. An inspection of fig. 14 shows, however, that the low-pressure area of the Atlantic is bounded to southward by systems of much higher pressures than are to be found in the Pacific. The result of this arrangement is that much stronger winds blow northward over the Atlantic and round upon Iceland; and, as these more quickly advance into colder latitudes, there is thus a greater and more frequent concentration of vapour and lowering of the barometer in the north of the Atlantic. The heavy rainfall of north-western Europe may be referred to as confirming this view.

A belt of low pressure passes through the equatorial regions quite round the globe. This marks the well-known region of calms towards which on either hand the trade winds blow. In the Atlantic it lies quite north of the equator even in January, when the sun's course is farthest to southward, and it lies nearly parallel with the equator. On the other hand, in the Indian Ocean the position of the line of lowest pressure is to the south of the equator and not parallel with it, but taking a slanting course from near the north of Madagascar towards Sumatra, thence towards the low pressure which prevails at this season in Australia; its course is then a little to northwards, and crosses the Pacific to the central regions of South America. Its path is thus a devious one, being north of the equator only in the eastern part of the Pacific and in the Atlantic, but elsewhere to the south of it, being drawn farthest southward when under the influence of the regions of low pressure which now occupy central Australia, central and southern Africa, and central South America. In this trough of barometric depression nearly all the tropical storms of the Indian Ocean have their origin.

There are several important modifications of the isobaric lines as originally published. In 1868 the region of lowest pressure in the northern hemisphere in winter was represented as extending from Iceland to north-eastward; now the area of lowest pressure is seen to extend from Iceland south-westward to Greenland. In connexion with this point Captain Hoffmeyer discussed the weather of the North Atlantic during several winter months, and published the results in 1878, which conclusively showed that the meteorology of Greenland and Iceland exerts on the distribution of atmospheric pressure a powerful influence not before properly recognized, resulting in the mean minimum of pressure being localized distinctly to the south-west of Iceland, and that in addition to this minimum there are two subordinate minima, one in Davis Straits and the other in the Arctic Ocean midway between Jan Mayen and the Lofoten Isles. The investigation further established the fact that, when any particular one of these three minima plays an important part, the other two either do not appear at all or occupy quite a subordinate place, and that according as one or other of these minima of pressure predominates so is the character of the weather, as regards mildness or severity, of the winter of north-western Europe and regions surrounding the North Atlantic. As regards the British Islands, the displacement of the minima to westward of the position shown in fig. 14 means milder winter weather, whereas a position more in the direction of the north of Norway means severer winter weather.

Another change implying important consequences is seen in the United States, where, instead of one, two distinct centres of maximum pressure occur, or rather the high pressure of the western and central States is separated from that of the south-eastern States by a region of lower pressure occupying the region of the Mississippi States. Professor Loomis first drew attention to this peculiarity in 1879 in an inquiry into the distribution of pressure over the United States, and established the fact that there are two distinct areas of high pressure, the larger having its centre in Utah, and the less overspreading the greater portion of the south-eastern and southern States, and that these two areas of high pressure are clearly separated from each other by a broad extensive region of lower pressure stretching in a south-western direction from the region of the great lakes to western Texas. The reason assigned by Professor Loomis is undoubtedly correct, that the relatively low normal pressure of the Mississippi States is due to the fact that the path usually taken by the barometric minima of American storms in the earlier part of their course is from Texas to the lakes. Since, on the other hand, the centres of comparatively few storms, with their low barometer readings, cross the southern and south-eastern States, the normal winter pressure is higher there than it is along the Mississippi.

Another important modification occurs in India, where the isobar of 30 inches is deflected to the south-east toward Madras and thence towards the north-east to near Akyab in Arakan. This remarkable deflexion well shows the important influence exerted on the course of the isobar by large well-defined sheets of water and extensive tracts of land. The distribution of pressure here indicated, by which south of lat. 22° the normal pressure is considerably higher in the east than in the west of India, has, through the agency of the winds resulting from it, the most intimate and vital bearings on the distribution of the winter rains and temperature over considerable portions of India; and the same relations hold, but in a degree still more striking, in the meteorology of Ceylon.

The remarkable effect in interrupting or changing the course of the isobars is particularly well illustrated by the lines in the region of the Aral, Caspian, and Black Seas. As the point is of no small importance in meteorology, and is best illustrated by the Mediter-

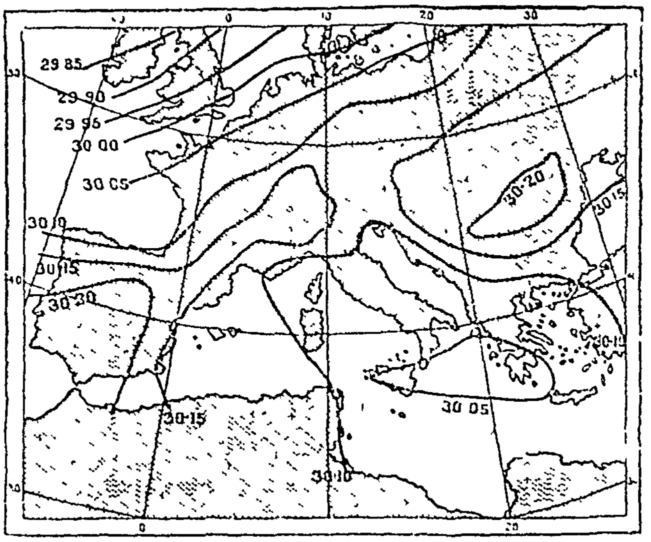

Fig. 15.—Isobars of Europe for January.

ranean and the countries to the north of it, we subjoin a map of this part of Europe (fig. 15), showing the normal pressure with greater distinctness and fulness than could be shown on fig. 14, the isobars being drawn for every half-tenth of an inch.

Here we see two distinct areas of high pressure, the one in Hungary and the other in the Peninsula, where the normal pressure exceeds 30·20 inches. The latter is the larger of the two, and may be regarded as the prolongation of the region of high pressure which characterizes the Atlantic immediately to the south-west at this season. The high-pressure area included within the isobar 30·15 inches is of peculiar interest. In the Peninsula it covers a pretty broad area, but to the north-east it contracts to a narrow neck between the Bay of Biscay and the Gulf of Lyons, and again expands to north-eastward covering the distance from Carlsruhe to Modena, its prolongation eastward being there somewhat suddenly interrupted. At some distance to the eastward the second region of high pressure is met with, which is properly a part of the high pressure that overspreads the interior of the Old Continent in the winter months, its western limit being the isobar of 30·15 inches, which passes round by Pinsk, Cracow, Vienna, Laibach and the upper southern slopes of the basin of the Danube, Sebastopol, and thence southward in the direction of Cyprus.

The position of the latter of these regions of high pressure is approximately midway between the south coasts of Asia Minor and the Baltic. In other words, its position occupies the interior of this part of the Old Continent; and it is instructive to note that the position of the Black Sea and the Greek archipelago in the south portion of this region pushes the isobar of 30·15 inches a good deal to northward. The position of the region of high pressure in the Peninsula, France, and Switzerland is also decidedly inland. It does not, however, exactly occupy the middle space of the land lying between the Mediterranean and the North Sea, owing no doubt to the circumstance that the very steep barometric gradient from France to Iceland greatly lowers the pressure over the whole of the northern half of France. It follows that the abnormally high pressure which so remarkably characterizes the interior of the Old Continent during the cold months of winter is represented, though in a greatly reduced form, westwards through the central districts of that continent.

These two regions of high pressure are separated from each other

by a large area of comparatively low pressure overspreading the greater portion of the Mediterranean Sea,—marked off in fig. 15 by the isobar of 30·10 inches, within which pressure is everywhere less than 30·10 inches. This region includes an area of still lower pressure within the isobar of 30·05 inches, bounded by Sicily, Corfu, Athens, and Crete. Hence the singularly low pressure which characterizes the northern part of the Atlantic at this season has its analogue in the south of Europe, which is unquestionably due to the higher temperature and larger humidity of the climates of southern Europe which they owe to the Mediterranean.

It is deserving of special notice that, while the increase of the normal pressure of January from Genoa to Geneva is 0·081 inch, it is only 0·021 inch from Trieste to Riva, and that to the north of the Adriatic as far as latitude 50° pressure is considerably lower than obtains to the west and east of that region. An examination of the daily weather maps of Europe shows that not unfrequently the storms of north-western Europe on advancing as far to eastward as Denmark seem to connect themselves in some degree with Mediterranean storms prevailing at the time through a north and south prolongation of a system of low pressures. The comparative frequency with which this occurs is probably occasioned by the general drift to eastward of the atmosphere of Europe, considered as a whole, taken in connexion with the high mountainous ridge which bounds the Adriatic on its eastern side, from which it follows that the air overspreading the deep basin of the Adriatic is often highly saturated with vapour, and this highly saturated air is drawn northwards through central Europe when north-western storms of Europe with low barometric depression centres pass across Denmark and the Baltic. Thus the low normal pressure to the north of the Adriatic, separating the two regions of high pressure to the east and west of it, is in some respects analogous to the low normal pressure of the Mississippi valley, which separates the higher normal pressures of the Rocky Mountains and of the south-eastern of the United States.

The influence of land and water respectively in the cold season of the year is well shown in fig. 16, which represents for every 0·020 inch the normal pressure over the British Islands in January, drawn from means calculated for two hundred and ninety-five stations.[1]

It is in the winter months that the isobars of the British Islands crowd most closely together, and in accordance therewith strong winds are then most prevalent. The crowding of the isobars reaches the maximum in January, forming what is probably the steepest mean monthly barometric gradient that occurs at any season anywhere on the globe. The point, however, to which attention is here drawn is the remarkable influence of St George's Channel and the Irish Sea in diminishing the pressures as they cross these seas, and of the land in increasing the pressure, which is seen in the curves occupying approximately the central districts of Great Britain from the Isle of Wight to Cape Wrath. This shows on a comparatively small scale the influence of the land in

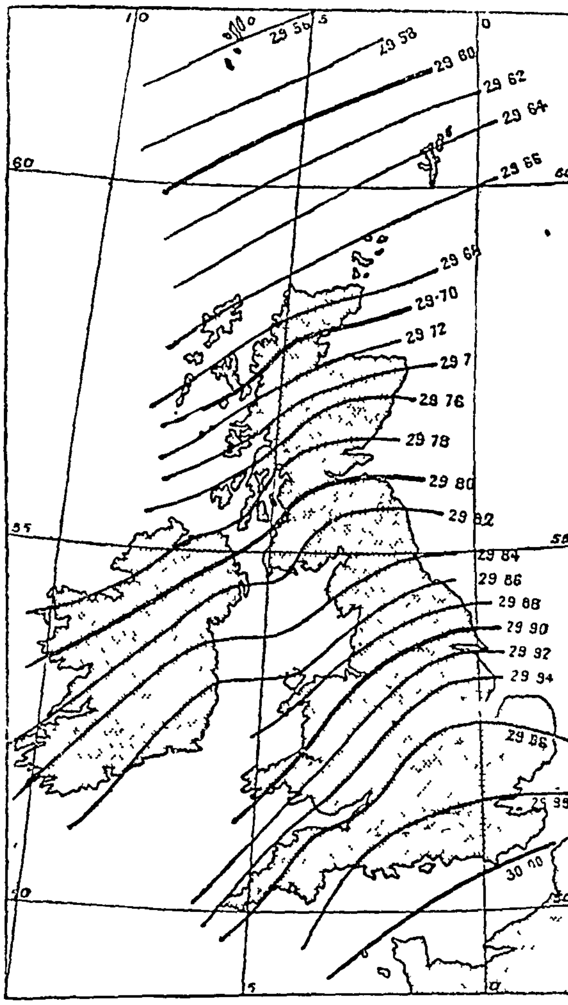

FIG. 16 —Isobars of the British Islands for January.

raising the normal pressure, and of the sea in lowering it, during the

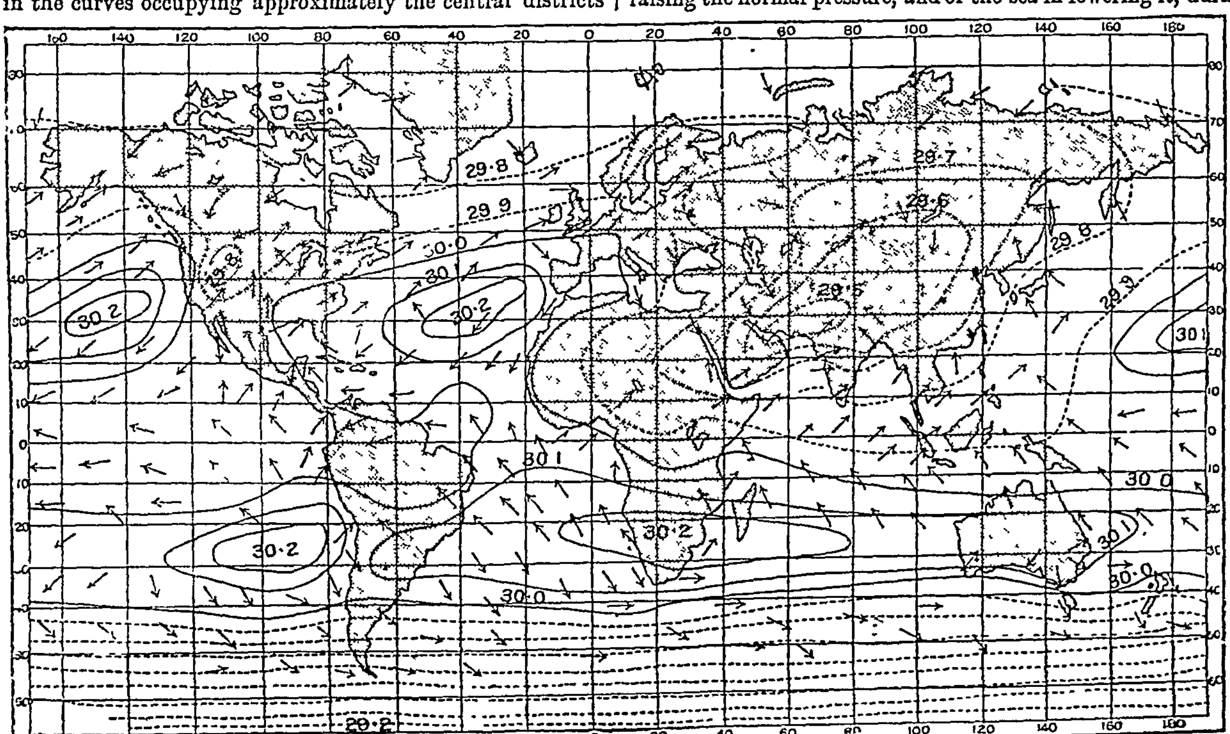

FIG. 17.—July Isobars of the Globe and Prevailing Winds.

cold months of the year, just as is seen on the grand scale in central Siberia and the north of the Atlantic.

Mean Atmospheric Pressure in July (fig. 17).—In this month the physical conditions are the reverse of what obtains in January, the effects of the influence of the sun on the temperature and humidity of the atmosphere rising to the maximum in the northern and fall-

[1] See *Journal of Scot. Meteorological Society*, vol. vi. pp. 4–21.

ing to the minimum in the southern hemisphere. With the solar conditions reversed, a comparison of figs. 14 and 17 shows that the distribution of atmospheric pressure in July is, considered in a broad sense, the reverse of what takes place in January.

In the southern hemisphere atmospheric pressure during the winter season is above the general average of 30 inches between lat. 10° and 40° S. This belt of high pressure encircles the globe, and embraces four regions where pressure rises considerably above this general high average. These regions are in South Africa, about lat. 20°, where it rises to a little above 30·20 inches; in Australia, where it rises on the Murray river very nearly to 30·20 inches; in South America, where in the basin of the La Plata, about lat. 30°, it rises to 30·13 inches; and in the ocean to westwards, where it reaches 30·02 inches. The point to be noted with respect to the position of these centres of high pressure at this season is that they occur over surfaces between latitudes 20° and 36°. As compared with January, pressure in July over nearly the whole of this broad belt of the southern hemisphere is about two-tenths of an inch higher, which is the simple result of season. A comparison of January and July shows that this large accession to the pressure of the southern hemisphere is accompanied by an extraordinary diminution of pressure over the continents of the northern hemisphere.

Now, just as the greatest excess of pressure during the winter of the northern hemisphere occurs in the continent of Asia, so the greatest diminution of pressure in the summer months takes place in the same continent. The position, however, of these two extremes is far from being in the same region or even near each other. In the Old Continent the maximum occurs in the valley of the upper Amur, where, at Nertchinsk, the normal pressure in January is about 30·500 inches; whereas the lowest normal pressure in July is 29·412 inches, and occurs, so far as observation enables us to locate it, at Jacobabad on the west side of the basin of the Indus. The difference of these two normals is 1·188 inch; and over no inconsiderable portion of central Asia the normal pressure of July is an inch less than that of January. In other words, the influence of the sun in summer as exerted on the temperature and aqueous vapour of the atmosphere and atmospheric movements resulting therefrom is so powerful as to remove a thirtieth part of the whole mass of the air from this extensive region.

The large extension in recent years of good meteorological stations over the Russian and Indian empires enables us to lay down with much greater precision than formerly the lines of pressure. Of the changes indicated by the new isobars, the most important perhaps is the position of the region of minimum pressure in Asia, which is now seen to occupy the basin of the Indus, and thence stretches over a somewhat broad region to westward nearly as far as the head of the Persian Gulf. The point is of no small importance in atmospheric physics, inasmuch as it places the region of least normal pressure in July as close geographically to the region where at the time terrestrial temperature is highest as the region of highest normal pressure in January is situated with respect to the region where in that month terrestrial temperature is lowest in Asia.

The July isobars of India are of singular interest, and imply consequences of the utmost practical advantage to the empire. From Cutch southward the normal pressure is everywhere higher, and considerably so, along the whole of the west than it is in the east in the same latitudes, the difference being approximately half a tenth of an inch. This is represented on the map by the slanting of the isobars from north-west to south-east as they cross this part of India; and it is to be noted that the east and west coasts of Ceylon show the same manner of distribution of the pressure. The consequence of this peculiarity in the distribution of the pressure is that the summer monsoon blows more directly from the ocean over western and southern India than would have been the case if the isobars had lain due east and west, and thus probably precipitates in its course a more abundant rainfall over this part of the empire. But a more important consequence follows from the geographical distribution of the pressure over the valley of the Ganges. If the normal pressure there had diminished in the manner it does over India to the south of the Gangetic valley, the winds would have been south-westerly and the summer climate practically rainless. This, however, is not the case, but the normal pressure diminishes westwards along the valley of the Ganges, as the following mean July pressures will show:—Calcutta, 29·576 inches; Patna, 29·535 inches; Lucknow, 29·522 inches; Roorkee, 29·505 inches; and in crossing westward into the Punjab pressure falls still lower—to 29·439 inches at Mooltan and 29·412 inches at Jacobabad. Indeed pressure in July is 0·220 inches lower at Jacobabad than at Sibsagar on the Brahmaputra, nearly in the same latitude. It necessarily follows from this distribution of the pressure that the summer monsoon, which blows northward over the Bay of Bengal, is deflected into an E.S.E. wind which fills the whole valley of the Ganges, distributing on its way a most generous rainfall over that magnificent region.

The influence of the land in lowering the pressure in summer is well illustrated by the course of the isobars over western Siberia and Russia, where pressure is seen to fall relatively lowest along the middle line of the Old Continent. In this connexion it is interesting to note the course of the isobar of 29·90 inches over that part of Europe where the breadth of the land is considerably increased—between the Baltic and Constantinople. In contradistinction to this the influence of the Aral, Caspian, and Black Seas in maintaining a higher pressure appears in the remarkable prolongation eastward of the isobars of higher pressure over the region of these seas, being in striking contrast to the lower pressures which prevail to the north and south.

The lowering of the normal pressure is very decided in the inland regions of Spain, North Italy, and Scandinavia. The effect is most strongly seen in Spain, the largest and compactest of these regions. Thus, while the normal pressure diminishes between Lisbon and Barcelona from 30·086 to 30·018 inches, the sea-level pressure at Madrid falls nearly to 30·000, and the pressure at Saragossa and Valladolid is nearly as low. This lowering of the pressure over the interior influences materially its summer climate. As remarkable an illustration of the principle as can be pointed to anywhere is seen in the north of Italy; for, while the normal pressure at Moncalieri is 29·941 inches, at Genoa on the coast the relatively high normal of 29·992 inches is maintained, the distance of the two places being about 40 miles. To the east pressure rises to 29·970 inches at Venice, and to westward to 30·023 inches at Geneva. Over Scandinavia, along the west coast from the Arctic circle southward, the normal pressure equals or exceeds 29·80 inches, the variation being comparatively small; and along the coast from the head of the Gulf of Bothnia to the south-east of Sweden pressure also exceeds 29·80 inches, and the increase from north to south proceeds at a slow rate. In, however, the strictly inland districts to the north-east of Christiania, which lie immediately to the east of the Scandinavian mountains, and sheltered by that lofty range from the winds of the Atlantic, pressure is considerably lower than it is along the east and west coasts of the peninsula. Owing to this peculiar distribution of the pressure, the winds which necessarily result from it give a much finer summer climate to the south-east of Norway and to the strictly inland part of Sweden than would otherwise be the case.

The remarkable curving northward of the isobar of 29·80 inches so as to include Lapland within it points probably to the influence of the White Sea and the wonderful lake system of Lapland in maintaining a higher summer pressure over that country, by which the northerly winds that blow towards the low-pressure region of Central Asia, to the serious deterioration of the summer climate of northern Siberia, do not extend so far to westward as Lapland.

The distribution of the normal pressure over North America is quite analogous to what prevails over Asia, but, the continent being less, the diminution of pressure in the interior is also correspondingly less. The highest normal pressure, 30·077 inches, is found in the south-east in Florida, and the lowest, 29·780 inches, in Utah, the difference being thus 0·297 inch. Another region of relatively high pressure is in the north-western States and British Columbia to the north; the maximum, near the mouth of the Columbia river, reaches 30·062 inches, being thus nearly as high as what occurs in Florida. These two regions are merely extensions of important high-pressure areas which at this season are highly characteristic features of the meteorology of the North Pacific and North Atlantic respectively.

Of these two regions of high pressure the one overspreading the Atlantic between the United States and Africa is the more striking, being not only the region where pressure is highest anywhere on the globe during the months of June, July, and August, but where the normal pressure reaches the highest point attained at any season over the ocean. The highest point reached by the normal pressure over the land at any season occurs, as has been pointed out, near the centre of Asia, or approximately in the middle region of the largest continuous land surface on the globe during the coldest months of the year. On the other hand, the highest pressure over the ocean occurs during the warmest months of the year, and not over the largest water surface, but in the middle regions of the North Atlantic, where the breadth is only about half that of the water surface of the North Pacific.

From the essential differences between these two sets of phenomena it may be inferred that the extraordinarily high pressure which is so marked a feature of the meteorology of Central Asia during the cold months of the year is a direct consequence of the lowering of the temperature of the land of Asia and of the atmosphere resting on it during the time of the year when the effects of solar radiation are at the annual minimum, and of terrestrial radiation at the annual maximum. But the determination of the place and time of highest pressure over the ocean must be regarded as indirectly brought about. The physical conditions under which it occurs are these:—it happens (1) at the time of the year when the earth presents the largest surface of land to the sun, and (2) over that part of the ocean which is most completely surrounded by these highly heated land surfaces. This high summer pressure of the Atlantic has its origin in the upper currents of the atmosphere.

Mean Atmospheric Pressure for the Year.—The distribution of the annual atmospheric pressure may be considered as representing

the sums of the influences directly and indirectly at work throughout the year in increasing or diminishing the pressure of the atmosphere. There are two regions of high pressure, the one north and the other south of the equator, which pass completely round the globe as broad belts of high pressure. The belt of high pressure in the southern hemisphere lies nearly parallel to the equator, and is of nearly uniform breadth throughout; but the belt north of the equator has a very irregular outline, and shows great differences in its breadth and its inclination to the equator. These irregularities wholly depend on the peculiar distribution of land and water which obtains in the northern hemisphere.

These two zones of high pressure enclose between them the comparatively low pressure of the tropics, through the centre of which runs a narrower belt of still lower pressure, towards which the trade-winds on either hand blow. Considered in a broad sense, there are only three regions of low pressure, the equatorial one just referred to, and one round each pole bounded by or contained within the zones of high pressure just described. The most remarkable of these, so far as it is known, is the region of low pressure about the south pole, which remains low throughout the year, playing the principal rôle in the wind systems of the Antarctic zone, in its heavy snowfall and rainfall, and in the enormous ice-bergs which form so striking a feature of the water of the Southern Ocean.

The depression around the north pole contains within its area two distinct centres of still lower pressure, the one filling the northern part of the Atlantic and the other that of the Pacific. Of these two the low-pressure area round Iceland is the deeper, and is probably occasioned by the steeper barometric gradients and stronger winds which prevail over the North Atlantic. The broad equatorial zone of low pressure also contains two distinct regions characterized by still lower pressures. The larger of the two stretches across southern Asia from Assam to the head of the Persian Gulf, and is entirely due to the very low pressures which form so marked a feature in the summer meteorology of that part of Asia. The regions of the middle Indus and upper Ganges occupy the centre of this low-pressure area, where normal pressure falls short of 29·80 inches. The second area of lowest equatorial pressure is in the centre of Africa.

It may be here pointed out that the whole of these areas of low mean annual pressure possess the common characteristic of an excessive amount of moisture in the atmosphere. The Arctic and Antarctic zones of low pressure, and the equatorial low-pressure zone generally, may be regarded as all but wholly occasioned by the comparatively large amount of vapour in their atmosphere. As regards the region of low pressure of southern Asia in summer, it is remarkable that, while the eastern half which overspreads the valley of the Ganges is characterized by a moist atmosphere and large rainfall, the western half of it is singularly dry and practically rainless, and that the central portion of this remarkable depression occupies a region where at the time the climate is one of the driest and hottest anywhere to be found on the globe. Hence, while the vapour is the more important of the disturbing influences at work in the atmosphere, the temperature also plays no inconspicuous part directly in destroying atmospheric equilibrium, from which result winds, storms, and many other atmospheric changes.

The Prevailing Winds of the Globe.—If atmospheric pressure were equal in all parts of the earth we should have the physical conditions of a stagnant atmosphere. Such, however, is not the case. Let there be produced a concentration of aqueous vapour over a particular region, or let one region show a higher temperature than what prevails around it, then from the different densities, and consequently different pressures thereby produced, the equilibrium of the atmosphere is destroyed, and, as might be expected from the laws of aerial fluids, movements of the air, or winds, set in to restore the equilibrium. Now every one of the isobaric maps we have given, as well as every isobaric map which has been made from recorded observations, indicates very considerable disturbance of the equilibrium at the surface of the earth. All observation shows that the prevailing winds of any region at any season of the year are simply the expression of the atmospheric movements which result from the disturbance of the equilibrium of the atmosphere indicated by the isobaric maps for that season and region.

All winds may be regarded as caused directly by differences of atmospheric pressure, just as the flow of rivers is caused by differences of level, the motion of the air and the motion of the water being both referable to gravitation. The wind blows from a region of higher towards a region of lower pressure,—in other words from where there is a surplus to where there is a deficiency of air; and this takes place whether the differences of pressure be measurable by the barometer, as is generally the case, or not readily measurable, as in the case of sea breezes, squalls, and sudden gusts of wind which are of short duration.

So far as is known, differences of atmospheric pressure, and consequently all winds, originate in changes occurring either in the temperature or the humidity of the air over restricted regions. Thus, if two regions contiguous to each other come to be of unequal temperature, the air of the warmer region, being specifically lighter, will ascend, and the heavier air of the colder region will flow in below to take its place. Of this class of winds the sea and land breezes are the best examples. Again, if the air of one region comes to be more highly charged with aqueous vapour than the air of surrounding regions, the air of the more humid region being lighter will ascend, while the heavier air of the drier regions will flow in below and take its place. Since part of the vapour will be condensed into cloud or rain as it ascends, heat is thereby disengaged, and the equilibrium still further disturbed. In this way originate gales, storms, tempests, hurricanes, and all the more violent commotions of the atmosphere, except some of the forms of the whirlwind, such as dust storms, in the production of which very great differences of temperature are more immediately and exclusively concerned.

The Trade-Winds.—From fig. 14, giving the isobarics for January, it is seen that atmospheric pressure in the Atlantic is lower near the equator than it is to north and south of it; and the arrows indicate that to the north of the tract of lowest pressure N.E. winds prevail and to the south of it S.E. winds. These are the well-known N.E. and S.E. trade-winds, which thus blow from regions of high pressure towards the tract of lower pressure situated midway between them. The trade-winds do not blow directly to where the lowest pressure is, but in a slanting direction at an angle of about half a degree. The deviation from the direct course is due to the influence of the rotation of the earth on its axis from west to east,—an influence to which all winds and all currents of the ocean are subject.

In virtue of this rotation, objects on the earth's surface at the equator are carried round towards the east at the rate of about 17 miles a minute. On receding from the equator, however, this rate of velocity is being continually diminished, so that at 60° N. lat. it is only about $8\frac{1}{2}$ miles a minute, and at the poles nothing. From this it follows that a wind blowing along the earth's surface in the direction of the equator is constantly arriving at places which have a greater eastward velocity than itself. As the wind thus lags behind, these places come up, as it were, against it, the result being an east wind. Since, therefore, the wind north of the equator is under the influence of two forces—one, the low pressure near the equator, drawing it southwards, and the other, the rotation of the earth, deflecting it eastwards—it will, by the law of the composition of forces, take an intermediate direction, and blow from north-east. For the same reason, south of the equator the south is deflected into a south-east wind.

In the Atlantic the north trades prevail between latitudes 7° and 30° N., and the south trades between latitudes 3° N. and 25° S. These limits are not stationary, but follow the sun, being farthest to the south in February and to the north in August. The tract of low pressure between these wind systems is named the region of calms, owing to the calm weather which often prevails there, and it is also characterized by the frequent occurrence of heavy rains. This region of calms varies its position with that of the sun, reaching its most northern limit, lat. 11° N.,

in August, and its most southern, lat. 1° N., in February. Its breadth varies from 3° to 8°, and it lies generally parallel to the equator. It is to be noted that, in the Atlantic, the region of calms is at all seasons north of the equator.

North and south trades also prevail in the Pacific Ocean, separated by a region of calms, which would appear, however, to be of less breadth and to be less clearly defined than is the region of calms in the Atlantic. In the eastern portion of the Pacific the region of calms lies at all seasons to the north of the equator, but in the western division it is considerably south of the equator during the summer months of the southern hemisphere, this southerly position being in all likelihood occasioned by the extraordinarily high pressure in Asia in its relations to the low pressure in the interior of Australia at this season. During the summer months of the northern hemisphere the region of calms wholly disappears from the Indian Ocean and from the western part of the Pacific Ocean, there being then an unbroken diminishing pressure from the latitude of Mauritius and Central Australia northwards as far as the low pressure of Central Asia.

Regions of light and variable winds and calms occur at the higher limits of the north and south trades. Except in the Pacific, where, owing to the greater breadth of that ocean, they spread over a considerable extent, these regions appear but in circumscribed patches, such as characterize the meteorology of the North and South Atlantic about latitudes 26° to 36°. Of these regions of calms the most important is that marked off by the high pressure in the North Atlantic, between the United States and Africa. This is the region of the Sargasso Sea, where the weather is characterized by calms and variable winds, and the ocean by its comparatively still waters. These are known to seamen as the "horse latitudes," and are essentially different from the equatorial region of calms. The latter, as has been stated, is the region of low pressure at the meeting of the north and south trades, where the climate is distinguished for its general sunlessness and heavy rainfall. On the other hand, the calm regions in the Atlantic and Pacific Oceans about the tropics have an atmospheric pressure abnormally high, clear skies, and the weather generally sunny and bright, with occasional squalls.

Numerous observations made in all parts of the globe establish the fact that, while the surface winds within the tropics are directed towards the equatorial region of calms in such a manner that the general intertropical movements of the atmosphere or prevailing winds are easterly, the prevailing winds of the north and south temperate zones are westerly. The westing of these great aerial currents is due to the same cause that gives easting to the trade-winds, viz., the rotation of the earth round its axis. For, as an aerial current advances into higher latitudes, it is constantly arriving at regions having a less rotatory velocity than itself; it thus outstrips them and leaves them behind; in other words, it blows over these places as a westerly wind.

While, however, the general prevalence of westerly winds has been established over the extratropical regions of Europe, Asia, Africa, America, and Australia, the directions which in different seasons and at different places are actually found to prevail often differ very widely from west. An examination of the winds at one hundred and fifteen places pretty well distributed over the northern hemisphere reveals the instructive fact that almost every place shows two maximum directions from which winds blow more frequently than from the other directions, and that one of these two directions shows a considerable excess over the other. Thus, for example, the following are, on a twenty years' average, the number of days at Greenwich each wind prevails during the year:—N., 41; N.E., 49; E., 23; S.E., 21; S., 34; S.W., 103; W., 38; N.W., 24; and calms, 32. Hence S.W. and N.E. winds are there more prevalent than winds from any other direction, and of these two winds the greater maximum direction is S.W. If the two maximum directions be sorted into groups, then the greater maximum direction occurs as follows:—

from S.S.W.	to	W.	at	47	places
,, W.N.W.	,,	N.	,,	33	,,
,, N.N.E.	,,	E.	,,	19	,,
,, E.S.E.	,,	S.	,,	16	,,

and the other maximum direction is

from S.S.W.	to	W.	at	20	places
,, W.N.W.	,,	N.	,,	22	,,
,, N.N.E.	,,	E.	,,	38	,,
,, E.S.E.	,,	S.	,,	32	,,

This result of observation, so different from what was long accepted as being in accordance with the generally received theory of the movements of the atmosphere, teaches the important lesson that the region towards which the extra-tropical winds of the northern hemisphere are directed is not the region of the north pole.

Prevailing Winds in January.—On examining fig. 14, which shows the distribution of atmospheric pressure in January, it is seen that pressure is abnormally low over the northern portion of the Atlantic—the lowest occurring between Iceland and South Greenland—from which it rises as we proceed in a S.W. direction towards America, in a S. direction over the Atlantic, and in a S.E. and E. direction over Europe and Asia. Now what influence has this remarkable atmospheric depression on the prevailing winds over this large and important part of the earth's surface? The arrows in the figure, which indicate the prevailing winds, and which have been laid down from observations, answer this question.

At stations on the east side of North America the arrows show a decided predominance of north-west winds; at the more northern places the general direction is more northerly, whereas farther south it is more westerly. In the Atlantic between America and Great Britain, in the south of England, in France and Belgium, the direction is nearly S.W. In Ireland and Scotland it is W.S.W.; in Denmark and the north-west of Russia S.S.W.; from St Petersburg to Tobolsk S.W.; on the west of Norway generally S.S.E.; and in Greenland, the north of Iceland, and about Spitzbergen N.E. Hence all the prevailing winds in January over this extensive portion of the globe may be regarded as the simple expression of the difference of atmospheric pressure which prevails over the different parts of the region. In truth the whole appears to flow vorticosely, or in an in-moving spiral course, towards the region of low pressure lying to the south-west of Iceland, and extending eastward over the Arctic Sea north of Russia. The only marked changes in these directions of the wind thus broadly sketched out are the deflexions caused by the various mountain systems which lie, so to speak, embedded in these vast aerial currents; of these the winds in the south of Norway afford excellent illustrations.

The influence which this peculiar distribution of the pressure over the north of the Atlantic exercises in absolutely determining the winter climates of the respective countries is most instructive. It is to this low pressure, which draws over the British Islands W.S.W. winds from the warm waters of the Atlantic, that the open, mild, and, it must be added, rainy winters of these islands are due. The same region of low pressure gives Russia and Western Siberia their severe winters; and it is the same consideration that fully explains the enormous deflexion of the isothermal lines from Norway eastwards and south-

eastwards over the Old Continent. Finally, the same low pressure draws over British America and the United States, by the N.W. winds which it induces, the intensely dry cold air-current of the Arctic regions. At Portland, Maine, which is swept by these cold north-westerly winds, the normal temperature in January is 23°·6, whereas at Corunna, on the coast of Spain, in nearly the same latitude, where south-westerly winds from the Atlantic prevail, the mean temperature of the month is 49°·1, or 25°·5 higher.

The region of low atmospheric pressure in the north of the Pacific is accompanied by prevailing winds over the region embraced by it and by climatic effects in all respects similar to the above. In Vancouver Island the prevailing winds in January are S.W., at Sitka E.S.E., on Great Bear Lake E.N.E., in Alaska N.E., in Kamchatka N.N.E., and in Japan N.W. In accordance with these winds the winter climate of Vancouver and adjoining regions is mild and humid, and that of the north-east of Asia dry and intensely cold.

On the other hand, abnormally high pressure rules over the continent of Asia at this season, and as regards this region of high pressure the arrows represent the winds as blowing outwards from it in all directions. Over the interior of Asia, where the highest normal pressures are, observations show a marked prevalence of calms and light winds, but around this central region the prevailing winds in January are—at Calcutta N., at Hong-Kong E.N.E., at Peking N.W., on the Amur W.N.W., S.E. at Nijnikolynisk and S.S.W. at Ustjansk (in the north of Siberia), and at Bogoslovsk S.W. Hence from this extensive region, where pressure is abnormally high, or where at this season there is a large surplus of air, the prevailing winds flow outwards in all directions towards the lower pressure which surrounds it. Owing to the excessive dryness of the air of Central Asia, terrestrial radiation is less obstructed there than anywhere else on the globe, and consequently the temperature falls very low, the mean of January at Werchojansk being – 55°·8, which is the lowest mean monthly temperature known to occur on the earth's surface. And, since the winds blow outwards from the dry cold climates of the interior, temperatures are low, even on the coasts. Of this China affords good illustrations. Thus the mean January temperature of Peking is 22°·7 and of Zi-ka-Wei, near Shanghai, 35°·4, whereas at Corfu and Alexandria the normal temperatures for January are respectively 50°·9 and 58°·0, or 28°·2 and 22°·6 higher than in corresponding latitudes on the coast of China.

The winds of the United States in winter, taken in connexion with the peculiar distribution of pressure already described, are very interesting. There are two regions of high pressure, one in the south-eastern States and the other and larger one in the region around Utah; and between these there is interposed a trough of lower pressure extending from Chicago to the south-west of Texas. On the western side of this depression the winds are north-westerly, but to the east of it they become W., W.S.W., and in some places S.W., and again on nearing the Atlantic seaboard they become north-westerly. In connexion with the region of higher pressure in the west, the prevailing winds are seen to flow outward from it. The normal pressure diminishes everywhere to southward of a line drawn from the Canaries to Bermuda, thence westward in nearly the same latitude to Texas, and then to west-north-west to San Francisco. The tract of lowest pressure stretches from the basin of the Amazon in the direction of the isthmus of Panama in about latitude 8° N., and thence is continued westward for a considerable distance into the Pacific in nearly the same latitude. It follows from this distribution of the pressure that the north trades in a more or less modified form prevail over South America to the north of the Amazon, and in the Pacific to the north of lat. 8° N., probably as far to westward as long. 150° W.

The low-pressure systems which prevail during the summer months in South America and South Africa have each its corresponding system of winds all round. It is, however, in Australia, as being the most compact and isolated continent, that the influence of the summer sun in lowering the pressure is best illustrated. In that continent the lowest pressure occurs in the region situated about midway between the north coast and the tropic of Capricorn, over which the normal pressure does not exceed 29·80 inches. Further, everywhere in Australia pressure diminishes from the coast on advancing upon the inland districts. It follows from this disposition of the pressure that all round the island the prevailing winds in summer blow from the sea towards the interior; and accordingly it is in these months that the greater part of the rain falls. From the low pressure of the interior southwards to Bass's Straits pressure rises continuously, the increase in the normal over this space being about 0·200 inch. To northward it also rises continuously to beyond the north of China, the increase on this side being about ¾ of an inch. In this case the greater part of the increase occurs over the continent, the rate of increase from the north of Australia to the Philippine Islands being only about the rate of increase which obtains southward towards Bass's Straits. It will be shown when the subject of the rainfall is examined that it is the relative excess of these high pressures, the one in the south of Australia and the other in the south-east of Asia, that determines the position of the area of low pressure in Australia in particular years, and with that position the degree and extent to which the whole of the northern portion of Australia is watered by the rainfall. Thus, when pressure is more than usually high in the south-east of Asia, and either low or not excessive in the south of Australia, then the low-pressure region is pushed farther southward into the interior, and with it the rainfall spreads inland over a wider area and to a greater depth.

Prevailing Winds in July.—In the winter of the southern hemisphere, the geographical distribution of pressure is exactly the reverse in Australia of what obtains during the summer months. Everywhere all round it increases on advancing from the coast into inland districts. The lowest pressure, about 30·00 inches, occurs on the north coast, and the highest over the basin of the Murray river and its affluents, where it rises generally to 30·18 inches. On the south coast it is generally about 30·12 inches, falling, however, at Gabo Island, in the extreme south-east, to 30·050 inches, and to 29·836 in the south of New Zealand. From the Murray river the diminution of pressure is continuous to the north, even to the low pressure of Central Asia. From this arrangement of the pressure, the prevailing winds blow from the interior towards the surrounding ocean all round Australia, with the single exception of the extreme south-west of the continent, where the prevailing winds are south-westerly, being here essentially an outflow of the high pressure which overspreads the Indian Ocean to the westward. As these S.W. winds are from the ocean, the rainfall at Perth in July is fully 6 inches, and it is high over south-western districts of West Australia. The prevailing winds round Australia are S.E. on the north coast, S.W. at Brisbane, W.N.W. at Sydney, N. at Melbourne, N.E. at Adelaide. These all represent an outflow from the high-pressure regions of the interior modified by the influence of the earth's rotation, and, in correspondence with the reversal of the distribution of the pressure, are directions the reverse of the prevailing winds of January.

In July the central and southern parts of Asia are

highly heated by the summer sun, and, besides, the rainfall over southern parts is excessive. Consequently atmospheric pressure is very low, being fully 0·40 inch lower in the Punjab than it is in the south of Ceylon. From the interior pressure rises continuously on advancing to the eastward, southward, westward, and northward, and from all these directions the prevailing winds of summer flow inwards upon the interior, and these bring rain or parching drought according to the vapour they bring from the ocean they have traversed, and according as they advance into warmer or colder regions. The prevailing summer winds of Asia, being an inflow inwards upon the interior, have, generally speaking, exactly the reverse direction of that prevailing in winter.

The winds of Europe are mainly determined by the extraordinarily high pressure of the Atlantic in its relations to the low-pressure systems of Central Asia and Central Africa at this time. The winds in the Spanish Peninsula are north-west; in the north of Africa they are northerly, and again north-westerly in Syria. The winds of the British Islands and western Europe have less southing and more northing than the prevailing winds of winter, and to the east of long. 40° E. they become decidedly north-west. It is to the Atlantic origin of these winds that the summer climates of these large and important regions owe the comparatively large rainfall of this season, it being at this time that the rainfall reaches the annual maximum. The bearing of the low-pressure areas and mountain systems of the north of Italy and Scandinavia on the climates of these countries will be afterwards referred to.

The centre of lowest pressure in North America is over the district about Utah, from which it rises all round, least to northward and most in south-easterly and north-westerly directions. In California N.W. winds necessarily blow inwards upon this central low-pressure area; and, as these winds pass successively over regions the temperature of which constantly increases, the summer climate is rainless. On the other hand, southerly and south-easterly winds from the Gulf of Mexico blow up the western side of the basin of the Mississippi inwards upon the low-pressure area of the centre, depositing in their course, in a rainfall more or less abundant, the moisture they have brought from the Gulf. To the north of lat 50°, and to westward of Hudson's Bay, the prevailing winds become easterly and north-easterly, distributing over Manitoba, Saskatchewan, and neighbouring regions, as they continue their westerly course towards the low-pressure area, the rainfall they have transported thither from the wide expanse of Hudson's Bay. An attentive examination of the arrows of fig. 17 shows that the prevailing winds over all the States to the east of the Mississippi river are rather to be regarded as an outflow from the region of very high pressure over the Atlantic to south-eastward. Thus in Florida the winds are S.E., in the southern States S., and in the lake region, in the New England States, and on the Atlantic seaboard S.W. Since the origin of these winds is thus essentially oceanic, and since in their course northwards no mountain range crosses their path, the whole of this extensive region enjoys a large but by no means excessive rainfall, which, taken in connexion with the temperature, renders the summer climate of these States one of the best to be met with anywhere on the globe for the successful prosecution of agricultural industries.

The remarkable protrusion of high pressures from the southern hemisphere, where they are massed at this time of the year, northwards into the Atlantic is, as has already been referred to, one of the outstanding features of the meteorology of the summer months of the northern hemisphere. In the central area of this large region the climate is remarkable for its prevailing calms, light winds, occasional squalls, and clear skies. From this comparatively calm space the wind blows outwards in all directions towards and in upon the surrounding regions of low pressure. These winds, owing to the high temperature, clear skies, and strong sunshine of the region from which they issue, carry with them a great amount of vapour near the surface, by which to a large extent the north of South America, the east of North America, the greater part of Europe, and a large portion of Africa are watered. The prevailing winds over this region are further interesting, not merely from the striking illustration they give of the intimate relation of the winds to the distribution of the pressure, but as being of no small importance in determining the best routes to be taken over this great highway of commerce, and the more so inasmuch as the currents of the ocean are coincident with these prevailing winds.

In the Antarctic regions, or rather to the south of lat. 45° S., the normal atmospheric pressure is low at all seasons, there being a gradual diminution of pressure to 29·20 inches about lat. 60° S. Pressure is probably even still lower nearer to the south pole, as seems to be indicated by the observations made by Sir James C. Ross, and in the "Challenger" and other expeditions. Over this zone the prevailing winds are W.N.W. and N.W. This is the region of the "brave west winds," the "roaring forties" of sailors, which play such an important part in navigation, and which determine that the outward voyage to Australia be round the Cape of Good Hope and thence eastward, and the homeward voyage eastward round Cape Horn, the globe being thus circumnavigated by the double voyage. That the general drift of these winds is inwards upon the south pole is strongly attested by the existence of the enormously thick wall of ice which engirdles these regions, from which are constantly breaking away the innumerable icebergs that cover the Southern Ocean, none of which is ever seen of a calculated thickness less than 1400 feet. The snow and rainfall which must take place in the south polar regions for the formation of icebergs of such a thickness must be peculiarly heavy, but not heavier than might be expected from the strength and degree of saturation of the "roaring forties" which unceasingly precipitate their moisture over these regions.

To sum up:—so far as the prevailing winds are concerned, it has been shown that where pressure is high, that is to say, where there exists a surplus of air, out of such a region winds blow in all directions; and, on the other hand, where pressure is low, or where there is a deficiency of air, towards such a region winds blow from all directions in an in-moving spiral course. This outflow of air-currents from a region of high pressure upon a region of low pressure is reducible to a single principle, viz., the principle of gravitation. Given as observed facts the differences of pressure, it is easy to state with a close approximation to accuracy what are the prevailing winds, before calculating the averages from the wind observations. Indeed so predominating is the influence of gravitation where differences of pressure, however produced, exist that it may practically be regarded as the sole force immediately concerned in causing the movements of the atmosphere. If there be any other force or forces that set the winds in motion independently of the force called into play by differences of mass or pressure, their influence must be altogether insignificant as compared with gravitation.

It has been abundantly proved that the wind does not blow directly from the region of high towards that of low pressure, but that, in the northern hemisphere, the region of lowest pressure is to the left of the direction towards which the wind blows, and in the southern hemisphere to the right of it. This direction of the prevailing wind with reference to the pressure is in strict accordance with Buys

Ballot's Law of the Winds, which may be thus expressed:—the wind neither blows round the centre of lowest pressure in circles, or as tangents to the concentric isobaric curves of storms or cyclones, nor does it blow directly towards the centre; but it takes a direction intermediate, approaching, however, more nearly to the direction and course of the circular curves than of the radii to the centre. The angle formed by a line drawn to the centre of lowest pressure from the observer's position and a line drawn in the direction of the wind is not a right angle, but an angle of from 60° to 80°.

From its importance in practical meteorology Buys Ballot's law may be stated in these two convenient forms. (1) Stand with your back to the wind, and the centre of the depression or the place where the barometer is lowest will be to your left in the northern hemisphere, and to your right in the southern hemisphere. This is the rule for sailors by which they are guided to steer with reference to storms. (2) Stand with the high barometer to your right and the low barometer to your left, and the wind will blow on your back, these positions in the southern hemisphere being reversed. It is in this form that the prevailing winds of any part of the globe may be worked out from the isobaric charts (figs. 14 and 17).

From the all-important consequences which flow from the geographical distribution of the pressure it is evident that the regions of low and of high normal pressure must be regarded as the true poles of the prevailing winds on the earth's surface, towards which and from which the great movements of the atmosphere proceed. From the unequal distribution of land and water, and their different relations to solar and terrestrial radiation, it follows that the poles of pressure and of atmospheric movements are, just as happens with respect to the poles of temperature, very far from being coincident with the north pole. Thus during the winter months the regions to which the origin of the great prevailing winds of the northern hemisphere are to be referred are Central Asia, the region of the Rocky Mountains, and the horse latitudes of the Atlantic, and the regions towards and in upon which they flow are the low-pressure systems in the north of the Atlantic and Pacific Oceans, and the tract of low pressure within the tropics towards which the trade-winds blow. In the summer months the reversed conditions of pressure-distribution then observed are attended with corresponding changes in the prevailing winds; and, generally speaking, if the south polar region be excepted, the poles of highest and lowest pressure and atmospheric movements are at no time coincident with the north pole. It is this consideration which affords the true explanation why prevailing winds at so large a proportion of stations in the northern hemisphere do not blow in the directions in which true equatorial and polar winds should blow.

The causes which bring about an unequal distribution of the mass of the earth's atmosphere are mainly these two—the temperature and the moisture of the atmosphere considered with respect to the geographical distribution of land and water. Owing to the very different relations of land and water to temperature, as already stated, the summer temperature of continents greatly exceeds that of the ocean in the same latitudes. Hence the abnormally high temperature which prevails in the interior of Asia, Africa, America, and Australia during their respective summers, in consequence of which the air, becoming specifically lighter, ascends in enormous columns thousands of miles in diameter. On arriving at the higher regions of the atmosphere it flows over neighbouring regions where the surface temperature is lower, and thus the atmospheric pressure of the highly heated regions is diminished.

Surface winds set in all round to take the place of the air removed from the continents by these ascending currents, and since these necessarily are chiefly winds from the ocean they are highly charged with aqueous vapour, by the presence of which, and by the condensation of the vapour into cloud and rain, the pressure over continents at this season is still further and very largely diminished. Air charged with vapour is specifically lighter than when without the vapour; in other words, the more vapour any given quantity of atmospheric air has in it the less is its specific gravity; and, further, the condensation of vapour in ascending air is the chief cause of the cooling effect being so much less than that which would be experienced by dry air. From these two principles, which were established by Dalton, Joule, and Sir William Thomson, it follows that the pressure of vapour in the air, and its condensation, exercise a powerful influence in diminishing the pressure. The great disturbing influences at work in the atmosphere are the forces called into play by its aqueous vapour; and it is to these, co-operating with the forces called into play by the differences of temperature directly, that the low normal pressure of the continents during the summer is to be ascribed. The degree to which the lowering of the pressure takes place is, as was to have been expected, greatest in Asia, the largest continent, and least in Australia, the smallest continent, while in America it is intermediate.

The influence of the aqueous vapour in diminishing the pressure is well seen in the belt of calms in the tropics between the north and the south trade-winds. Since these winds import into the belt of calms the vapour they have taken up from the sea on their way thither, the climate is characterized by a highly saturated atmosphere and heavy rains. Again the air in regions near the Atlantic contains much more vapour and is of a higher temperature during winter than is observed at places in the interior of continents in the same latitudes. It follows thus that the air over the north of the Atlantic and the regions adjoining is specifically lighter than in the regions which surround them. We have here therefore the physical conditions of an ascending current; and it is plain that the strength of this current will not merely be kept up but increased by the condensations of the vapour into cloud and rain which take place within it, by which a higher temperature and a greater specific lightness are maintained at the surface of the earth and at various heights in the atmosphere than exist over surrounding regions at the same heights. Accordingly it is seen from the winter isobars that an enormous diminution of pressure occurs over these regions, and also over the north of the Pacific and the Antarctic, as compared with the continents.

Since, on the other hand, dry and cold air is specifically heavy, the winter isobars show that where temperature is low and the air very dry pressure is high. Of this Asia and North America are striking examples during December, January, and February, and Australia, South Africa, and South America during June, July, and August.

Since vast volumes of air are thus poured into the region where pressure is low without increasing that pressure, and vast volumes flow out of the region where pressure is high without diminishing that pressure, it necessarily follows that the volumes of air poured into the region of low normal pressure do not accumulate over that region, but must somehow escape away into other regions, and that the volumes of air which flow out from the region of high normal pressure must have their place supplied by fresh accessions of air poured in from above. That the same law of relation observed between sea-level pressures and surface winds obtains between pressures at different heights and winds at the same heights is simply a necessary inference. We are therefore justified in expecting that

ascending currents will continue their ascent till a height is attained at which the pressure of the air composing the currents equals or just falls short of the pressure over the surrounding regions at that high level. On reaching this height the air, no longer buoyed up by a greater specific levity than that of the surrounding air, will cease to ascend, and expanding horizontally will thenceforth flow over as an upper current towards those regions which offer the least resistance to its course; that is to say, it will flow over upon those regions where, at that height, pressure happens at the time to be least. Now from the known densities of air of different temperatures and humidities it is evident that the overflow of the upper current will take place towards and over that region or regions the air of which in the lower strata of the atmosphere happens to be colder and drier than that of the other surrounding regions,—because, being denser, a greater mass of air is condensed or gathered together in the lower strata of the atmosphere, thus leaving a less mass of air, or a diminished pressure, in the higher region of the upper current.

If this be so, then the extraordinarily high pressure of Central Asia during winter is to be ascribed to these two causes:—(1) the low temperature and excessive dryness of the air of this extensive region; and (2) its relative proximity to the low pressure of the Atlantic to the north-west, the low pressure of the Pacific to the north-east, and the low pressure of the belt of calms to the south. Similarly, since in summer the temperature of air resting over the Atlantic between Africa and the United States is much lower than that of the land, the ascending currents which arise from the heated lands of Africa, Europe, and North and South America, as well as from the region of calms immediately to the south, all of which are remarkable for a low normal pressure, will on reaching the upper regions of the atmosphere flow towards this part of the Atlantic, because there, the temperature being lower and the density of the air composing the lower strata being greater, pressure in the upper regions is less. And, since the surface winds are constantly flowing outwards from this region of abnormally high pressure, thus draining away the air poured down upon it by the upper currents which converge upon it, extreme saturation does not take place, and the air consequently is relatively dry and cool. That this view generally represents the movements of the upper currents has been strongly confirmed within the last few years by Professor Hildebrandsson and Clement Ley in their researches into the upper currents of the atmosphere based on observations of the cirrus cloud.

From these considerations it may be concluded that the winds which prevail near the earth's surface are known from the isobaric lines, the direction of the wind being from regions where pressure is high towards regions where it is low, in accordance with Buys Ballot's law; and that the upper currents may be inferred from the isobaric lines taken reversely, together with the isothermal lines taken directly. In other words, the regions of lowest pressure, with their ascending currents and relatively higher pressure at great heights as compared with surrounding regions, point out the sources or fountains from which the upper currents flow; and the isothermals, by showing where on account of the relatively low temperatures the greater mass of the air is condensed in the lower strata of the atmosphere and sea-level pressure consequently is high, thus diminishing the pressure of the upper regions, point out the regions towards and upon which these upper currents of the atmosphere flow. The facts of the diurnal oscillations of the barometer in the different regions already discussed afford the strongest corroboration of these views.

The term "monsoon" has long been applied to the prevailing winds in southern Asia which blow approximately from S.W. from April to October, and from N.E. from November to April. The term is now, however, generally applied to those winds connected with continents which are of seasonal occurrence, or which occur regularly with the periodical return of the season. Since they are caused immediately by the different temperatures and pressures which form marked features of the climates of continents in winter and summer respectively, they are most fully developed round the coast of Asia, owing to the great extent of that continent. The monsoons of different parts of the coasts of Asia differ widely in direction from each other. Thus in winter and summer respectively they are W.N.W. and E.N.E. at the mouth of the Amur, N. and S.S.E. at Shanghai, N.E. and S.W. at Rangoon, N. and W.S.W. at Bombay, N.W. and S.W. at Jerusalem, and S.S.W. and N.N.E. at Archangel. The Indian winter monsoon generally begins to break up in March, but it is not till about the middle of May, when the normal pressure has been decidedly diminished over the heated interior, that the summer monsoon acquires its full strength and the heavy monsoonal rains fairly set in. In October, when the temperature has fallen considerably and with the falling temperature the pressure of the interior has risen, the summer monsoon begins to break up, and this season is marked by variable winds, calms, and destructive hurricanes. As the temperature continues to fall and pressure to rise, the winter monsoon again resumes its sway. Monsoons, equally with the trade-winds, play a most important part in the economy of the globe. The relatively great force and steadiness in the direction in which they blow, and the periodical change in their direction, give facility of intercourse between different countries; and, besides, by the rainfall they bring they spread fertility over extensive regions which otherwise would be barren wastes.

The winds of Australia are also strictly monsoonal, but owing to the small extent of that continent, and consequently the smaller differences there are between the normal pressure of the interior and that of the surrounding coasts in summer and winter respectively, they are less strongly marked than are the monsoons of southern Asia; and particularly they neither blow with the same force nor so steadily from the same point of the compass. For the same reason the Australian climates are characterized by the occurrence of more frequent droughts than are the climates of southern Asia, and the same remark applies to the climates of southern Africa.

Since the Malay archipelago lies during the summer of the northern hemisphere between the high pressure of central Australia and the low pressure of Asia, and during the winter between the high pressure of Asia and the low pressure of central Australia, it follows that the winds of these islands are eminently monsoonal in their character, being in summer southerly and in winter northerly. The result of this peculiar wind system of the archipelago is to give to these islands a singular diversity of climates, which will be more particularly referred to under rainfall.

At Zanzibar the prevailing wind in July is S.E., but in January, when the low pressure of the interior is situated much farther to southward, it is N.E.; and the same influence is felt, though in a greatly modified degree, as far as Mauritius, where the S.E. trade changes nearly into E. during the summer. On the other side of Africa the S.E. trade of the South Atlantic is changed into a S.W. monsoon on the coast of the Gulf of Guinea.

In the southern, central, western, and northern regions of North America the prevailing winds have a well-marked monsoonal character. The prevailing winds of winter and summer respectively are N.E. and S.S.E. at New Orleans,

N.W. and S.W. in Utah, N. and S. at Fort Yuma (California), E.S.E. and N.W. at Portland (Oregon), and S. and E.N.E. at Fort York, Hudson Bay. These winds are readily accounted for by the distribution of pressure over the continent in winter and summer. On the Atlantic seaboard of the United States the prevailing winds of winter vary from N.W. in the New England States to W. in South Carolina; whereas in summer they vary generally from S.S.W. in South Carolina to S.W. in the New England States. Hence over the eastern States the summer winds are not directed towards the low-pressure region of the interior of the continent, but are determined by the relations of their pressure to the high pressure of the Atlantic to the eastward, and to the lower pressure overspreading the Atlantic to the N.E. This influence of the Atlantic may be considered as felt westward through the States as far as the Mississippi.

Though not so decidedly marked, the winds of Europe, except the extreme south, are also monsoonal. In winter they flow from the land towards the region of low pressure in the north of the Atlantic; but in summer the arrows, representing the prevailing winds, show that all but the extreme south of Europe is swept by westerly winds, which flow in a vast continuous stream from the Atlantic towards the central regions of the Old Continent, and which deposit in their course the rains they have brought from the ocean.

Similarly, monsoons prevail on the coasts of Brazil, Peru, North Africa, and many other regions which happen to lie between other regions whose temperatures, and therefore pressures, differ markedly from each other at different times of the year.

These are the chief prevailing winds of the globe when the differences of the normal atmospheric pressure are such as to cause a decided and steady movement of the atmosphere over a large portion of the earth's surface, resulting in well-marked prevailing winds. But there are other winds which are greatly influenced by local causes, such as the nature of the ground, whether covered with vegetation or bare; the physical configuration of the surface, whether level or mountainous; and the vicinity of extensive sheets of fresh or salt water. An important characteristic of winds in their practical relations to climate is their quality,—they being warm or cold, dry or moist, according to their direction and the nature of the earth's surface over which they have just passed. Thus in the northern hemisphere southerly winds are warm and moist, while northerly winds are cold and dry. In Europe southwesterly winds are moist and easterly winds dry, while in the New England States and Canada north-easterly winds are cold and raw and north-westerly winds cold and dry.

In particular regions certain meteorological conditions occur at stated seasons intensifying these effects, resulting in excessive drought, heavy rains, intense or great heat, thus giving rise to the following among other well-known winds. The east winds of the British Islands occur chiefly in spring, but also in a less degree in November, being in the latter case often accompanied with fog. The winds here referred to are dry and parching, and their deleterious influence on the health is seen, not merely in the discomfort and uneasiness they impart to the less robust of the population, but also in the largely increased mortality which they cause from consumption and all other diseases more or less connected with the nervous system. In the countries bordering on the north of the Atlantic, atmospheric pressure reaches the annual maximum in May, and it is above the average during the other two spring months. In these months the normal pressure approaches nearer to what obtains farther south, and an examination of daily weather maps shows that this is due to the repeated occurrence in spring of very high pressures in the north of Europe while pressures much lower prevail to southward. Now these east winds are simply the outflow from these regions of high pressure to northward. Northerly and even westerly winds which are truly outflows from what may be styled Arctic anticyclonic areas bring with them qualities as noxious as those of the east wind itself, and prove as injurious to health and vegetation. The cold dry wind of April 29, 1868, which blasted and shrivelled up vegetation in Scotland, particularly in the western counties, as effectually as if a scorching fire had passed across them, was a west wind.

In the south of Europe, during the winter and early spring, peculiarly dry, cold, and violent northerly winds are of occasional occurrence. Of these winds the "mistral" is one of the most notorious, which is a steady, violent, and cold north-west wind blowing from central and eastern France down on the Gulf of Lyons. It is particularly trying while it lasts to invalids who are spending the winter at the various popular sanataria which are scattered along this part of the Mediterranean coast. The great cold that took place in the north of Italy and south of France in the beginning of 1868 was a good example of the mistral. The meteorological conditions under which it occurred were unusually low pressure over the Mediterranean to southward (29·450 inches), whilst at the same time pressure rose steadily and rapidly on proceeding northward to 30·905 inches in the north of Russia. From this geographical distribution of the pressure, northerly winds swept southwards over Europe, carrying with them the low temperatures of the higher latitudes, and became still colder and drier on crossing the Alps before they made the descent on the shores of the Mediterranean. The cold tempestuous winds which descend from the Julian Alps and sweep over the Adriatic, and the dreaded "gregale" of Malta, which is a dry cold north-east wind, are in their character and origin quite analogous to the mistral.

The "northers," or "nortes," are peculiarly dry cold strong winds which repeatedly occur from September to March in the States bordering on the Gulf of Mexico, and are perfectly analogous to the mistral. The conditions under which they occur are a pressure lower than usual to the south or south-east over the Gulf of Mexico, together with a pressure even higher than the high normal which is so marked a feature of the meteorology of the Rocky Mountains during the colder months. When, as most frequently happens, they occur in the wake of a storm, their disagreeable qualities of extreme dryness, cold, and violence are all intensified. From a temperature of upwards of 80° experienced as the storm comes up the thermometer rapidly falls to 18° or even lower; and, as the low temperature often occurs with a wind blowing with great violence, the northers prove most deleterious. A violent wind with a temperature of 18° is altogether unknown in the British Islands.

The "pampero" is a strong, dry, cold wind which blows across the pampas of the River Plate of South America, occurring at all seasons, but most frequently during the spring and summer from October to January. They are preceded by easterly winds, a falling pressure, a rising temperature, and increased moisture. A pampero is described by Dr D. Christison, and its appearance figured, in the *Journal of the Scottish Meteorological Society*, vol. v. p. 342, as seen advancing on the morning of November 28, 1867, in central Uruguay. In the early morning the wind blew rather strongly from north-east, and by and by clouds were seen moving very slowly from the west, throwing out long streamers eastwards. As they advanced, two dense and perfectly regular cloud-masses appeared in front, one behind the other, in close contact yet not intermingling,—the one being of a uniform leaden grey, while the other was as black as the smoke of a steamer. On arriving overhead, the front, though slightly wavy in appearance, was seen to be quite straight in its general direction, and the bands were of uniform breadth. They rushed forward at great speed under the other clouds without uniting with them, preserving their forms unbroken, being borne onward by an apparently irresistible force, as if composed of some solid material rather than vapour. They extended probably 50 miles in length, but as they took only a few minutes to pass their breadth was not great, and they appeared to diminish to mere lines in the distant horizon. At the instant the first cloud-band arrived overhead, the wind chopped round from north-east to north and then to south-west; a strong cold blast at the same time seemed to fall from the leaden cloud, and continued to blow till both bands had passed. No rain or thunder occurred at this time, but in the confused rabble of clouds which followed low thunder continued to roll, and in a quarter of an hour rain fell, and for some hours thereafter wind, rain, and thunder continued, but only to a moderate degree. The low temperature and rising barometer and change of wind are the constant and most striking characteristics of the pampero. On one occasion the temperature fell 44° in fourteen hours, and on another occasion the fall was only 4°. Rain is a usual accompaniment, but on rare occasions the pampero passes off and no rain falls.

Rainfall.—Whatever tends to lower the temperature of the air below the dew-point is a cause of rain. It is therefore to the winds we must chiefly look for an explanation of the rainfall, and the broad principles of the connexion may be stated to be these five:—(1) when the winds have previously traversed a considerable extent of ocean, the rainfall is moderately large; (2) if the winds advance at the same time into colder regions, the rainfall is largely increased, because the temperature is sooner reduced below the point of saturation; (3) if the winds, though arriving from the ocean, have not traversed a considerable extent of it, the rainfall is not large; (4) if the winds, even though having traversed a large extent of ocean, yet on arriving at the land proceed into lower latitudes or regions markedly warmer, the rainfall is small or nil; (5) if a range of mountains lies across the onward path of the winds, the rainfall is largely increased on the side facing the winds, and reduced over the regions on the other side of the range. The reason here is that, the air on the windward side of the ridge being suddenly raised to a greater height in crossing the range, the temperature is further reduced by mere expansion, and a more copious precipitation is the result; whereas on the leeward side as the air descends to lower levels it becomes gradually drier, and accordingly the rainfall rapidly diminishes with the descent.

We have drawn attention to the diminished velocity of the wind over land as compared with the open sea (p. 125). From this it follows that an envelope of stiller air or air of less velocity than that of the prevailing wind broods over the land, and by its presence forces the prevailing wind to a greater height, thus tending to increase the rainfall. If the foreshore rises within a few miles to a height of 200 or 300 feet, the result is very striking when the wind from the sea blows straight upon it. Thus at Spittal, near Berwick, on September 1877, a N.E. wind blew straight ashore at an estimated velocity of 25 miles an hour. To eastward the sky was singularly clear down to the horizon, but to westward all the country beyond a mile from the shore was enveloped in what appeared a dense mist or fog. About 15° to eastward of the zenith of an observer on the shore, the thinnest rack of cloudlets was seen emerging without intermission from the deep stainless blue of the sky, which as they drifted landward increased so rapidly in volume and density that the zenith was three-fourths covered with clouds. A similar phenomenon was seen in September 1879 on board the Orkney steamer at the magnificent cliff of Hoy Island, Orkney. A heavy storm had just cleared away, and a strong W.N.W. wind was blowing right against the cliff. The sky was absolutely cloudless all round, except the upper 300 feet of Hoy Hill, 1570 feet high, which was enveloped in a thick mist that stretched away to windward, some distance to westward of the steamer's course, which was about 2 miles from land. The western termination of the cloud was the thinnest rack of cloud, which emerged unceasingly from the blue sky at a distance not less than 4 miles to windward of the cliff. The constituent parts of the cloud itself were in rapid motion eastward, but, owing to the fresh accessions it was constantly receiving, the cloud itself appeared stationary. Thus the wind was forced upward into the atmosphere for some considerable distance to windward of the ridge lying across its path.

It is this dragging effect of the land on the wind, and the consequences which result from it, that explain how it is that during storms of wind and rain from the north-east the rainfall over the foreshores of the Firth of Forth, the Moray Firth, and the Pentland Firth looking to the north-east is so much in excess as compared with the rest of Scotland. The same principle explains the heavy rainfall in plains at some distance from the range of hills lying across the wind's path and on the side of the rain-bringing winds.

For short intervals of time the heaviest rainfalls occur with tornadoes, waterspouts, and some other forms of the whirlwind, the reason being that not only is there rapid expansion due to the rapid ascent of the air, but also great rarefaction is produced by the extreme velocity of the aerial gyrations round the axis of the tornado. On August 1, 1846, 3·12 inches of rain fell at Camberwell, London, in two hours and seventeen minutes. Of heavy falls may be mentioned 4·60 inches in London, April 13, 1878; 6·00 inches at Tongue, September 7, 1870; 5·36 inches in Monmouthshire, July 14, 1875; 6·62 inches at Seathwaite, Cumberland, November 27, 1848; and 7·12 inches at Drishaig, Argyllshire, December 7 to 8, 1863. But it is in lower latitudes that the heaviest single showers have been recorded. The following are among the most remarkable:—at Joyeuse, France, 31·17 inches in twenty-two hours; at Genoa, 30·00 inches in twenty-four hours; at Gibraltar, 33·00 inches in twenty-six hours; on the hills above Bombay, 24·00 inches in one night; and on the Khasi Hills, India, 30·00 inches on each of five successive days.

As regards the ocean, there are no available data from which an estimate could be formed as to the amount of the rainfall, since the rainfall statistics of the ocean must be regarded as giving hardly anything more than the comparative frequency of the fall. It is, however, certain that the equatorial belt of calms in the Atlantic and Pacific between the trades is the region where the ocean rainfall reaches the maximum, and the parts of these oceans are the rainiest which are the longest within the belt of calms as it shifts its position northward and southward with season. While the cloud-screen is undoubtedly dense, and the rainfall frequent and heavy, the careful observations of the "Challenger" and "Novara" show that the statements generally made as to these points are greatly exaggerated.

In the regions of the trades the rainfall is everywhere small over the open sea, seeing that the trade-winds are essentially an outflow from anticyclonic regions, and their original dryness is to a large extent maintained because their course is directed into regions which become constantly warmer. Thus at Ascension, lat. 8° 45′ S., which is throughout the whole year within the S.E. trades, the mean rainfall for the two years 1854–55 was only 8·85 inches. At St Helena, which lies constantly within the same trades, five years give a mean rainfall of 5·36 inches on the coast; but in the same island at a height of 1763 feet the annual amount rises to 23·98 inches. Malden Island and some other islands in the Pacific, about long. 150° W., and for some distance on each side of the equator, have been pointed to by Scott as practically almost rainless, as is shown by their containing extensive guano deposits. These islands are situated somewhat similarly to Ascension with respect to the zone of calms. In Mauritius the annual rainfall on a mean of four years was 30 inches at Gros Cailloux, but at Cluny, only 16 miles distant, for the same four years it was 146 inches; in regard to which Meldrum remarks that at Cluny, which is in the vicinity of mountains and forests, in the south-east of the island, and thus directly exposed to the trade-wind as it arrives from the sea, the rainfall in almost any month is from four to six times greater than at Gros Cailloux on the north-west coast, where neither mountain nor forest exists, and where the S.E. trade arrives considerably drained of its moisture.

From what has been said it is evident that the heaviest rains will be brought by the winds which have traversed the greatest extent of ocean within the tropics, and which accordingly of all ocean winds have the highest temperature and humidity. These conditions are most completely fulfilled during the summer months of the northern hemisphere by the winds which, commencing from near lat. 30° S., blow home on southern Asia as the well-known S.W. monsoon of these regions. Accordingly it is by the winds of this monsoon that a larger rainfall is distributed over a larger portion of the earth's surface than occurs anywhere else in any season; and this large rainfall is in many regions still farther greatly increased by the mountain ranges which lie across the path of the rain-bringing winds.

It is on these winds that the rainfall of India chiefly depends. Along the whole of the west coast from the

Gulf of Cambay southward, and on the Western Ghats, the rainfall is excessive. The following are some of the more interesting annual means in inches beginning with Bombay and proceeding southwards:—Bombay, 74; Matheram, 247; Mahabaleshwar, 252; Ratnagiri, 104; Baura, 255; Goa, 102; Karwar, 115; Honawar, 139; Mangalore, 134; Cannanore, 132; Calicut, 116; and Cochin, 114. In the west of Ceylon the rainfall is also heavy, being at Colombo 87, at Galle 91, and at Ratnapura, at some distance inland among the hills, 149. Since the S.W. monsoon is drained of much of its moisture in crossing these mountains, a greatly diminished rainfall is distributed over the interior and east side of India, and on the eastern slopes of Ceylon.

If now we cross to the eastern shores of the Bay of Bengal, we again encounter an excessive rainfall along these coasts and up the slopes of the mountains looking down on them. Thus from south northward the following are among the more characteristic rainfalls in inches:—Nancowry, 102; Port Blair, 116; Mergui, 152; Tavoy, 196; Maulmain, 189; Rangoon, 100; Bassein, 98; Sandoway, 212; Akyab, 198; and Chittagong 104. On the other hand, at Thyetmio, inland on the Irawadi, the annual rainfall is only 48 inches.

We have shown how, in accordance with the peculiar distribution of pressure in India in summer, the monsoon is diverted up the valley of the Ganges as an E.S.E. wind, distributing on its way, even to the head of the valley, in a generous rainfall the moisture it has brought from the Indian Ocean and the Bay of Bengal. The rainfall does not extend farther westward than the basin of the Ganges, and the precipitation is most copious along the lower Himalayas, the largest falls being recorded at heights about 4000 feet,—being, as pointed out by Hill, near the level at which the summer monsoon is cooled just below its dew-point. The following are some of the larger rainfalls in inches, beginning with the more western:—Mussooree, 95; Naini Tal, 92; Khatmandu, 57; Darjiling, 121; Kurseong, 154; Buxa, 219; Kuch Behar, 131.

The rainfall is very large in the north-east angle of the Bay of Bengal and thence northwards towards Bhutan, or at the angle where the summer monsoon from the bay curves round to a westerly course on its way up the Ganges. Thus at Noakhally, on the coast, it amounts in inches to 109; at Tura, on the Brahmaputra, immediately to west of the Garo Hills, 129; at Silchar and Sylhet to eastward, 117 and 155; whilst at Cherrapunji, on the Khasi Hills, it rises to 493·19 inches on a mean of twenty-four years. This last rainfall is the largest known on the globe, the causes of which are the highly saturated state of the monsoon on its arrival at the lower Ganges, the high mountain range of Burmah to eastward of Bengal, which turns the monsoon to the north, and the protrusion westwards of the Khasi and Garo Hills so as to lie in the line of that branch of the monsoon which passes from the lower Ganges into the basin of the Brahmaputra above Goalpara. The consequence is that the highly saturated air of the monsoon in its passage across the Khasi Hills is suddenly raised to a height of about 6000 feet, and being thereby reduced far below the point of saturation the superabundant moisture is precipitated in unequalled deluges of rain. The amount of the annual rainfall at all these places is determined, essentially if not altogether, by the rains of the summer monsoon, the relative intensity of which over India may be taken to be fairly represented by the rainfall of July.

The rains which accompany the N.E. monsoon of the winter months may be represented by the rainfall for January. These are heaviest in Ceylon, especially on its east slopes, and in southern India, or where the N.E. monsoon arrives after having traversed a large extent of ocean. The fall for the month exceeds 6 inches over a large portion of the east coast, whilst at Colombo in the west the rainfall is only half that amount, and farther north at Pattalum the January rainfall is only 1·82 inches. In southern India the amount varies from about 1 to 2 inches. Blanford pointed out in 1873 (*Phil. Trans.*, vol. clxiv. p. 618) that, while the surface winds of northern India in winter are northerly, on the Himalayas, especially the north-west portion, southerly winds prevail during the cold months. It is these upper southerly winds which bring the winter rains to the Punjab, Upper India, and the highlands of Assam. It is further to be noted that winter rains also occur in Central India, where the prevailing surface winds are from east and north-east. The mean rainfall of January at Mussooree is 2·00 inches and at Naini Tal 2·86 inches, and in Assam, at Sibsagar, 1·13 inch. Over a large tract of the east side of southern India from Nellore southward, including Ceylon, the maximum rainfall for the year occurs in the months of October and November.

Rainfall of the Malay Archipelago and Australia.—Under the direction of the late Dr Bergsma, systematic observations of the rainfall of the Malay archipelago were begun in 1879, the number of stations being 150. The results of the first three years show that the mean annual rainfall over the archipelago varies from about 60 inches in Timor to upwards of 200 inches at some spots among the western slopes of Sumatra. But the most important feature in the rainfall in its relations to climate is not the absolute amount that falls annually, but rather the manner of its distribution through the months of the year. Over the greater number of the islands rain falls copiously every month; but as regards some of the islands the year is divided into dry and wet seasons as marked as are seen in the climates of India. The key to this essential difference among the climates is the distribution of atmospheric pressure during the months of the year from south-eastern Asia to Australia, with the resulting prevailing winds. During the winter months atmospheric pressure is high in south-eastern Asia and low in the interior of Australia, the difference being about three-quarters of an inch. Since between these two regions the fall in the mean pressure is practically uninterrupted, the Malay archipelago lying between them is swept by northerly winds (fig. 14). As these winds have traversed a great breadth of ocean in their course, they arrive in a highly saturated state, and consequently deposit a copious rainfall, particularly on the northern slopes of the higher islands. Hence in these months the rainfall over the islands without exception is large, the mean monthly amount being in many cases more than 30 inches. These winds continue their course to southward towards the low-pressure region in the interior of Australia, and deposit along the north coasts of that continent a monthly rainfall rising generally to from 14 to 20 inches. On advancing into the interior, the mean amount gradually diminishes at the successive telegraphic stations to 3·50 inches at Alice Springs near the tropic of Capricorn. The amount of the rainfall for any particular year, and the distance from the coast to which the rains penetrate inland, depend essentially on the height of the winter pressure of south-eastern Asia as compared with the low mean pressure of central Australia, by which the strength of the northerly monsoon is regulated.

On the other hand, during the summer of the northern hemisphere pressure is high in the interior of Australia and low in China, the mean difference being about half an inch. Between the two regions the fall in the mean pressure is continuous and uninterrupted, and as a consequence southerly winds prevail over the intervening archipelago. These winds, as they advance from the continent into lower latitudes, are absolutely rainless in the north of Australia, and over Timor and the other Malay islands which are separated from Australia only by a comparatively narrow belt of sea. During the three years no rain whatever fell in Timor in July and August, and the fall in June, September, and October was small. As, however, the winds pursue their course to northward, they eagerly lick up moisture from the sea, so that by the time they arrive at Amboyna they have become so saturated that the monthly rainfall there rises to nearly 30 inches. Again at some distance to the west of Timor rain falls more or less regularly every month, the amount increasing in proportion to the extent of ocean traversed by the S.E. winds, which advance towards these islands from the direction of Australia. These marked differences among the climates of the Malay archipelago, which, since they really depend on the geographical distribution of land and sea of this part of the globe, must be regarded as permanent differences, have played no inconspicuous part in the singular distribution of animal and vegetable life which characterizes the archipelago.

In July the prevailing wind in West Australia is N.W., and the rainfall reaches the maximum for the year, whereas in January the wind is S.E., and the rainfall is the minimum. Similarly in January since the winds of the southern half of South Australia and Victoria are from the south, and thus blow towards warmer regions, the rainfall is either at the annual minimum, or it is small. But on rounding the coast and proceeding northward, the wind becomes E., then N.E., and ultimately N. in the north of Queensland. With this prevalence of oceanic and equatorial winds, the rainfall at this time of the year rapidly rises over the whole of the eastern slopes, till at Cape York it is about 20 inches. In the basins of the Murray and Darling rivers, which are shut off from the east by the mountain ranges of New South Wales, the rainfall is only about an inch and a half. On the other hand, to south of the latitude of Sydney, including Tasmania, the maximum rainfall occurs in winter over those regions which slope south towards the sea. On crossing the mountain range of Victoria into the basin of the Murray river, the rainfall rapidly diminishes. In the north of New Zealand the winter rainfall is the heaviest; but farther south, where westerly winds prevail with some steadiness through the year, the rainfall is more equally distributed through the months; and, as the prevailing winds are westerly, the heaviest rainfall is in the west of the islands. Thus at Hokitika in the west near sea-level, and not far from a lofty range of mountains to the east, the annual amount reaches 120 inches, and at Bealey inland at a height of 2104 feet it is 106 inches. At Wellington the annual rainfall is 52 inches, at Southland 46, at Dunedin 34, and at Christchurch 25, thus showing, in the rainfall of the two sides of the island, extremes nearly as great as in Scotland.

Rainfall of Europe.—As regards rainfall, Europe may be conveniently divided into two distinct regions,—western and northern Europe, extending in a modified degree through the interior of the continent into Siberia, and the countries bordering on the Mediterranean. A vast ocean on the one hand, a great continent on the other, and a predominance of westerly winds are the determining circumstances in the distribution of the rainfall over western Europe. Hence the rainiest regions are to be found in the west, where mountain ranges stretch north and south. The annual rainfall exceeds 80 inches over a considerable district, including the greater part of Skye and portions of the counties of Inverness and Argyll to the south-east, in the lake district of England, and in the more mountainous parts of North Wales,—these three districts being the wettest in Europe. As Ireland presents no continuous range of mountains opposing the westerly winds of the Atlantic, no Irish rain-gauge shows a mean rainfall of 80 inches. A point of some interest is suggested by the rainfall of the counties of Kirkcudbright and Dumfries in Scotland. These counties offer to the westerly winds a series of valleys sloping south to the Solway Firth, which show successively a diminished rainfall on advancing eastward till at several places in Nithsdale and Annandale it does not exceed 40 inches. But in Eskdale, farther to the east, the rainfall instead of falling increases to about 60 inches. The reason is that the westerly winds are obstructed in their onward course by the range of hills by which Eskdale is bounded on the east, in surmounting which the winds are much reduced in temperature, and their superabundant moisture falls in copious rains immediately to westward of the ridge. The cause of the larger rainfall of Eskdale is thus analogous to that of the large rainfall of the coast in the north-east of the Bay of Bengal immediately under the Assam range of mountains. In England the largest annual rainfall is 146 inches at Seathwaite in the Lake district, in Scotland 128 inches at Glencroe in Argyll, whilst in Ireland the largest is only 76 inches. The driest part of the British Islands is an extensive district to south-south-west of the Wash, with a rainfall of about 21 inches. A large extent of England, and all the more important agricultural districts in Scotland, have a rainfall under 30 inches: the greater part of England, and nearly the half of Scotland, have a rainfall not exceeding 40 inches; but in Ireland it is isolated patches only that show a rainfall less than 40 inches.

In the west of Norway the rainfall in inches is 72 at Bergen, 51 at Aalesund, 46 at the Naze and in the Lofoten Isles, falling to 10 at the North Cape. At Christiania, Upsala, and a large part of the east of Scandinavia the rainfall is about 21 inches, falling to 16 inches on the north coast of the Gulf of Bothnia. In Russia and Siberia it rises only at a few places to 20 inches, several districts of this extensive region having an annual rainfall of 10, 5, 3, or even 2 inches. The rainfall of Spain presents great extremes—from 68 inches at Santiago to 13 inches at Saragossa. In France and the plains of Germany the average varies from 35 to 20 inches, but in mountainous regions these figures are greatly exceeded, rising through all gradations to upwards of 100 inches at some points in the Alps.

An important distinction between the manner of distribution of the rainfall in the west of Europe and at more inland places is that the greater part of the annual quantity of the west falls in winter, whilst in the interior the amount in summer is greater than in winter. The rainfall of January and July shows this in a very forcible manner. The summer climates of the extreme south of Europe and North Africa are rainless, and over extensive regions in the south of Europe adjoining the July rainfall does not amount to an inch. Over these dry regions the prevailing winds of summer are northerly, and hence the drought which characterizes them. On the other hand, the rainfall in the interior of the continent is large. In January the maximum rainfall occurs on the mountains and high grounds overlooking the Atlantic, and the minimum on the plains of Russia.

Owing to the way in which Europe is broken up by the seas which diversify its surface, the time of the year when the rain attains the maximum differs greatly in different regions. This phase of the rainfall occurs, indeed, according to locality, in all months except February, March, and April. The month of occurrence of the annual maximum rainfall over Europe is shown by fig. 18. A similar map

FIG. 18.—Showing Month of Maximum Rainfall in Europe.

representing the month of least rainfall shows still greater uniformity in a regular succession of the months in passing from region to region. Thus the month of least rainfall is January on the lower Volga, February in western Russia and the greater part of central Europe, March in the north of France and south of Great Britain, April farther to the north,

May in Scotland north of the Grampians, June in Orkney, Shetland, Iceland, the west of Ireland, and the north-west of France, and July over the whole of the south of Europe. The driest month occurs nowhere in Europe in any of the five months from August to December.

Rainfall of North America.—West of the Rocky Mountains the rainfall is very unequally distributed, the annual amounts varying from 86 inches at Astoria, near the mouth of the Columbia river, to 8 inches at San Diego on the coast, and 3 inches at the head of the Gulf of California. Over the whole of the region between the Cascade and Rocky Mountains the rainfall at all seasons is extremely small, this being indeed that feature in the climate to which the formation of the cañons of that region is chiefly to be referred. On the other hand, in the United States and Canada to east of long. 100° W. the distinguishing feature of the rainfall is the comparative equableness of its distribution, an annual rainfall exceeding 50 inches occurring only over restricted districts, and a rainfall as low as 20 inches being scarcely met with anywhere. The regions where the rainfall exceeds 50 inches are Florida, the lower basin of the Mississippi, and the Atlantic seaboards of Nova Scotia and Newfoundland.

In January the annual maximum rainfall occurs over the whole of the west coast from Sitka to lower California; but in the interior between long. 120° and 95° W. the amount is everywhere small, and over a considerable part in the south-west of this region no rain falls. The region of largest rainfall extends from Louisiana to West Virginia, where the mean varies from 4 to 6 inches. Over nearly the whole of the Dominion of Canada, by much the greater part of the winter precipitation is in the form of snow, which has been carefully measured and recorded by the Meteorological Service. The average snowfall for January exceeds 30 inches at St John's, Newfoundland, in Anticosti, Prince Edward Island, and in many other regions.

In July the rainfall is everywhere small in the west, a large part of this extensive region being absolutely rainless. The remarkable dryness of the climate at this season is due to the N.W. winds that set in towards the low pressure of the interior, which thus blow towards warmer regions. The rainfall to the east of the Rocky Mountains is distributed by the winds which are connected with the low-pressure region of the interior and with the high-pressure region of the Atlantic. The result is two regions of larger rainfall, the one in the south-east of the States and the other to the west of the lakes. The summer winds of the south-eastern coasts are southerly, and as they are anticyclonic in their origin and have in their course traversed some extent of ocean, they arrive well- but not super-saturated, and pour down a rainfall in July of 6 inches and upwards along the coasts and for some distance inland from Louisiana to Chesapeake Bay. Further, since in July these winds attain their maximum force and persistency, the rainfall at the same time reaches the maximum along the whole coast from Boston to some distance west of New Orleans. Since the summer winds blow in the line of the Alleghany mountains and not across them, the rainfall diminishes in ascending their slopes. The comparative equableness of the rainfall over the eastern States is the necessary result of the winds' passing into higher latitudes, and, therefore, cooler regions. A broad region where the rainfall is less than on each side of it, extends from Michigan to the south-west as far as Canadian River. To the west of the lakes the rainfall rises above 4 inches, and, since over this region the winds become somewhat easterly as they flow towards the low-pressure area, it is probable that the larger rainfall of this prairie region has its origin in no small degree in the evaporation of the lakes. On ascending the higher reaches of the Mississippi, the amount diminishes, but scarcely falls lower than 2 inches, being thus analogous to the summer rains of the Upper Ganges. On crossing the water-parting into the basin which drains into Hudson Bay, we encounter E. and N.E. winds laden with vapour licked up in their passage over Hudson's Bay, which they distribute in a generous rainfall of probably 3 to 5 inches over the rising colonies of Manitoba and Saskatchewan. An important point in the climate of the States is that over nearly the whole of the extensive region stretching between Alleghanies and Rocky Mountains, except the south coast already referred to, the annual maximum rainfall does not occur in summer but in spring, the month of largest rainfall in the great majority of cases being May. In the basin of Hudson's Bay July is the month of largest rainfall.

Rainfall of Central and South America.—The following are, in inches, the larger and more interesting annual rainfalls round the coasts:—Vera Cruz, 182; Belize, 75; Maracaibo, 163; Carácas, 155; Georgetown, 95; Paramaribo, 142; Cayenne, 140; Para, 71; Pernambuco, 109; Buenos Ayres, 34; Bahia Blanca, 19; Puerto Montt, 102; Valdivia, 109; Valparaiso, 100; Serena, 93; Lima, 9; and a large part of Peru, nil. A remarkable feature of the rainfall of South America is the large amounts that fall in the basins of the Orinoco and Amazon; the fall is 91 inches in the upper basin of the Madeira, and 112 inches at Yquitos (lat. 3° 40′ S., long. 72° 57′ W.). The reason is that this immense region, where pressure appears to be almost constantly low, is open to the highly saturated winds that blow from the equatorial Atlantic. Quite different is the distribution of the rainfall over the La Plata basin. The annual falls, in inches, are 92 at Joinville, 58 at Corrientes, 44 at Monte Video, 36 at Parana, 24 at Santiago, 22 at San Luis, and only 6 at Mendoza. The fall rapidly rises in ascending the eastern slopes of the Brazil mountains facing the South Atlantic; thus, while the amount at Rio Janeiro is 45 inches, on the hills to northward it is 116 inches.

In January northerly winds prevail on the south coasts of the Gulf of Mexico and the Caribbean Sea, and as they have their origin in the high pressure of the American continent, and in crossing the sea pass into lower latitudes, the January rainfall of these coasts is comparatively small. In July, however, the prevailing winds are easterly, and as they have traversed a large extent of the equatorial waters of the Atlantic they are highly saturated, and consequently the July rainfall of these coasts is everywhere very large. The following are, in inches, the January and July rainfalls:—Carácas, 1·00 and 14·04; Guatemala, 0·28 and 10·79; Vera Cruz, 5·10 and 35·90. The seasonal distribution of the rainfall in the basin of the Amazon is the reverse of this. In January the position of the belt of calms is about lat. 3° N., and as pressure is relatively low over the basin of the Amazon, especially its southern slopes, the trades and the west portion of the region of calms unitedly spread their highly saturated air over the whole region as far as the Andes, resulting in one of the most widespread heavy rainfalls anywhere to be met with. On the other hand, since in July the belt of calms is about lat. 10° N., the saturated atmosphere of the tropical regions no longer flows up the Amazon, but is carried westward into the Caribbean Sea and Gulf of Mexico. Hence at this season the rainfall of the Amazon valley is small. The following are, in inches, the January and July falls:—Para, 6·51 and 3·26; Manaos, 7·33 and 1·82; upper Madeira, 15·90 and 0·30; and Yquitos, 10·24 and 4·26. On the La Plata in January pressure is low, and as winds consequently blow from the ocean in upon the region of low pressure the rainfall is large; but as pressure is high in the interior in July the rainfall in that month is small. The following are, in inches, the January and July rainfalls:—Buenos Ayres, 2·37 and 1·70; Parana, 4·63 and 1·32; Corrientes, 5·24 and 2·67; Joinville, 14·26 and 3·55; and San Luis, 2·63 and 0·00.

Rainfall of Africa.—As regards the rainfall, Africa presents the greatest diversity in its climates. The following are the annual amounts in inches at various points on or near the coast:—Port Said, 2; Alexandria, 8; Tunis, 12; Algiers 31; Oran, 17; Mogador, 50; mouth of the Senegal, 17; Goree, 21; Sierra Leone, 126; Christiansborg, 23; St Thomas, 40; Gaboon, 106; Loanda, 11; Cape Town, 23; Mossel Bay, 12; Port Elizabeth, 24; Durban, 43; Zanzibar, 58; and mouth of the Zambezi, 61. In the north of the continent, the rainfall rapidly diminishes inland, and over the great desert of Sahara practically none falls. In the interior of Algiers it diminishes, the amount at Laghouat being 17 inches, and at Biskra 9. In Egypt the rainfall is limited to a narrow strip along the coast; at Cairo the annual fall scarcely amounts to an inch. The January and July rainfalls are, in inches, as follows:—Port Said, 0·46 and 0·00; Alexandria, 1·95 and 0·20; Algiers, 4·43 and 0·04; Biskra, 0·56 and 0·03; St Louis (Senegal), 0·28 and 3·00; Goree, 0·00 and 4·06; Sierra Leone, 0·69 and 24·20; Christiansborg, 0·50 and 2·00; Katunga, 0·11 and 4·76; Gaboon, 9·35 and 0·48; Cape Town, 0·28 and 3·83; Durban, 5·00 and 1·70; Pretoria, 6·07 and 0·71; and Zanzibar, 2·02 and 2·35. At Zanzibar the heaviest rains occur about the equinoxes, the mean for April being 14·55 inches, and for October 6·80 inches.

In the case of this, as the other continents, the explanation of the different amounts is to be had in the seasonal changes of wind. In the north the winter rains are to a very large extent the accompaniment of the Mediterranean storms of that season, but in summer pressure is diminished in the interior and increased in the Atlantic to the north-west, resulting in strong steady northerly winds, which as they advance into hotter regions are unaccompanied with rain. The heavy summer rains from Senegambia to the Gold Coast are due to the strong monsoonal winds which set in towards the interior, thus drawing over these coasts the highly saturated air of the belt of calms and of the trades immediately to the north and south of it. Since in winter the belt of calms is removed 8° of latitude farther to the south, and the temperature of the interior is greatly reduced, it follows that the winds blowing on these coasts from the sea are drier and less strong, and consequently the rainfall is small. At Sierre Leone the absolutely driest month is February, 0·31 inch, and the wettest September, 29·15 inches. On the other hand, at Gaboon (lat. 0° 25′ N.) the dry season is from June to August, when the belt of calms is farthest to the north; and the absolutely rainiest about the equinoxes, the mean of March being 14·70 inches and October 19·52 inches. At Loanda (lat. 8° 49′ S.) the annual amount is only a tenth of what falls at Gaboon, and it

falls wholly during the summer months of the southern hemisphere. In South Africa pressure in January is lowest in the interior, towards which prevailing winds from the ocean blow, and as these advance into regions becoming rapidly hotter the rainfall all round the coast and for some distance inland falls to the annual minimum. But in more strictly inland districts which are at a considerable elevation the rainfall reaches the maximum at the same season. Thus the amounts in inches for January and July are—for Pretoria, 6·07 and 0·71; Maritzburg, 4·23 and 0·21; Graham's Town, 2·89 and 1·51; Lower Nel's Poort, 1·33 and 0·49; and Aliwal North, 1·55 and 0·00. In the winter months pressure in the interior is high, and the rainfall consequently small. Though on the coast winds from the arid interior frequently prevail, yet the storms that sweep eastward past South Africa precipitate over large portions of the southern slopes of this part of the globe what must in the main be regarded as a generous rainfall. It follows that the climates of these important colonies range themselves into two perfectly distinct classes,—the climates of the inland regions and the Natal coast, where the rains occur during the hottest months, and the climates of the other regions, where the annual rains occur during the coldest months. Little is accurately known regarding the rainfall of the interior of Africa. It is certain, however, that it is small, or nil, over the extensive region of the Sahara, and that it is large from about 15° N. lat. to some distance south of the equator. Probably the rainiest part of Africa is the region extending from the Victoria Nyanza northwards to and including the gathering grounds of the two great tributaries of the Nile.

Snow.—Snow takes the place of rain when the temperature is sufficiently low to freeze the condensed moisture in the atmosphere. Snow is composed of crystals, either six-pointed stars or hexagonal plates, which exhibit the greatest variety of beautiful forms, one thousand different kinds having been observed. These numerous forms Scoresby reduced to five principal varieties:—(1) thin plates, comprising several hundred forms of the most exquisite beauty; (2) a nucleus or plane figure, studded with needle-shaped crystals; (3) six-sided, more rarely three-sided, crystals; (4) pyramids of six sides; (5) prismatic crystals, having at the ends and middle thin plates perpendicular to their length. In the same snowfall the forms of the crystals are generally similar. The flakes vary from 0·07 inch to an inch in diameter, the smallest occurring with low temperatures and the largest when the temperature approaches 32°. If the temperature is a little higher, the snow-flakes are partially thawed in falling through it, and fall as sleet. The white colour of snow is caused by the combination of the different prismatic colours of the minute snow-crystals. The density of snow is far from uniform; it is generally from ten to twelve times lighter than an equal bulk of water, but varies from eight to sixteen times lighter than water.

The limit of the fall of snow near sea-level coincides roughly with the winter isothermal of 52°, since in places where the mean winter temperature is no higher than 52° that of the air falls occasionally to 32° or lower during the winter months. As regards Europe, the southern limit is about Gibraltar; in North America it is Savannah, New Orleans, the mouth of the Rio Grande, the head of the Gulf of California, and San Francisco. In Europe, north of lat. 60°, snow falls generally on an average of from 80 to 110 days in the year. At Upsala the number of days is 61, at Warsaw 45, Aberdeen 42, Oxford 18, Ostend 15, Brussels 27, Tarum (in the south-west of Jutland) 12, Copenhagen 23, Vienna 33, Odessa 19, Sebastopol 12, Milan 11, Trieste 6, Saragossa 5, Madrid 3, and Lisbon 1. In Greenland the number of days exceeds 80, and this figure is nearly reached in Newfoundland and the north-east seaboard of Nova Scotia. At Quebec the mean days of snow are 66, Halifax 64, Winnipeg 54, Detroit 34, Cape Henry 13, St Louis 11, mouth of the Columbia River 7, and Charleston, S.C., 2. In Russia the time of the year when snow falls most frequently is December and January, except in the south of the empire, where February is the month of the most frequent occurrence of snow. But to the north of a line drawn from the entrance of the Gulf of Finland through Warsaw, Cracow, Salzburg, and Santiago March is the month of maximum occurrence in the great majority of instances; while to the south of this line it is January and in several cases December.

The largest falls of snow occur in the Antarctic regions, as is well attested by the magnificent icebergs of solidified snow which break off all round from the lofty walls of ice that engirdle the Southern Ocean. Excepting perhaps in the Dominion of Canada, no data have been anywhere collected from which even a rough estimate could be formed as to the mean annual amount of snow that falls in different parts of the globe.

Snow-Line.—The snow-line marks the height below which all the snow that falls annually melts during summer. No general rule can be stated for this height in different climates owing to the many causes determining it. These are the exposure of mountain slope to the sun (and hence, other things being the same, it is higher on the south than on the north sides of mountains), exposure to the rain-bringing winds, the steepness of the mountains, and the degree of dryness of the air. Hence the position of the snow-line can be known by observation only. It falls only little on either side of the equator to lat. 20°; from lat. 20° to 70° it falls equably, but from lat. 70° to 78° much more rapidly. To this general rule there are many exceptions. It is 4000 feet higher on the north than the south side of the Himalayas, owing to the larger snowfall on the south, and the greater dryness of the climate of the north side, and therefore the greater evaporation from the snow there. It is higher in the interior of continents than near the coasts, because the precipitation is less and summer heat greater. In the Caucasus it is 11,063 feet high, but only 8950 in the Pyrenees. In South America it rises from the equator to lat. 18°, and more on the west than on the east slopes of the Cordilleras, owing to the large precipitation on the east and small precipitation and arid climate of the west side of that chain of mountains. It is as high in lat. 33° S. as in 19° N., but south of that latitude it rapidly sinks owing to the heavy rains brought by the moist N.W. winds of these regions. In the south of Chili it is 3000 feet lower than in the same latitudes in Europe, and 6000 feet lower than in the extremely arid climates of the Rocky Mountains.

Storms.—If weather charts representing a large part of the northern hemisphere be examined, two distinct systems of pressure are seen which change their forms and positions on the earth's surface from day to day. The one set are systems of low pressure marked off by concentric isobars enclosing pressures successively lower till the centre is approached; and the other systems of high pressure marked off by concentric isobars enclosing pressures becoming successively higher towards the centre. The former of these are called cyclones, and the latter anticyclones. These areas of low pressure are the distinguishing characteristics of the hurricanes and typhoons of tropical regions, and of the ordinary storms of higher latitudes, and they may all be conveniently grouped under the general name of cyclones. Fig. 19 shows a storm which was passing across north-western Europe on the morning of November 2, 1863, and it may be taken as fairly representing the general features of cyclones. In the figure the arrows fly with the wind, and the force of the wind is indicated by the number of feathers on the arrows.

It will be seen that the winds indicate, not a circular movement round the centre of lowest pressure, but a vorticose motion inwards upon that centre, the motion being opposite to that of watch-hands. In other words, the wind follows Buys Ballot's law, already explained. The winds are strongest where the isobars are closest together; or they are generally proportioned to the "baro-

metric gradient,"—a term introduced by Stevenson in 1867. Cyclones have diameters seldom less than 600, and they occasionally exceed 3000 miles; the cyclone of fig. 19 had a diameter of about 1200 miles. The cyclones of the Mediterranean are usually of smaller dimensions than those of north-western Europe and America. The rates at which cyclones advance over the earth's surface vary greatly, the average in America being 24 miles an hour, in the Atlantic 20 miles, and in Europe 26 miles. A rate as high as 70 miles an hour has occurred in the British Islands; sometimes they remain stationary, and more rarely their course is for a time retrograde. The temperature and humidity increase at those places towards and over which the front part of the storm is advancing, and fall at those places over which the front part of the storm has already passed. In other words, the temperature and humidity rise as pressure falls and fall as pressure rises. This is the important climatic significance of cyclones. Thus a succession of low pressures passing eastwards in courses lying to northward of the British Islands are the essential conditions of open winters; whereas, if the cyclones follow courses lying to southward, the winters are severe. In a cyclone the broadest feature of weather is an area of rain about or rather somewhat in front of the centre, surrounded by a ring of cloud, outside which the sky is clear. The precise form and position of these areas have been shown by Abercrombie to vary with the type of pressure distribution, with the intensity of the cyclone, and with the rate of its progress, and they are also influenced by local, diurnal, and seasonal variations.

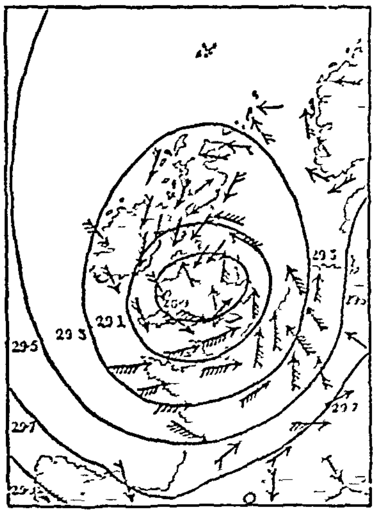

Fig. 19.

The chief point of difference between American and European storms is essentially the result of the mean winter pressures to the west and north-west of their respective storm-tracks. Owing to the high winter pressure in the interior of America, the barometer rises in the wake of the storms of the United States more rapidly, the wind veers round more quickly and more uniformly to N.W., N.N.W., and N. and keeps longer in these directions, and the temperature and humidity fall to a greater degree, than happens in Europe. In the New England States and Canada the easterly winds of the storms, coming as they do from the Atlantic, are disagreeably cold, damp, and misty in a degree and with a frequency much greater than occurs with the same winds in the British Islands.

The chief points of difference between the hurricanes and typhoons of the tropics and the cyclones of higher latitudes are these:—tropical cyclones are of smaller dimensions, show steeper barometric gradients and therefore stronger winds, and advance at a slower rate over the earth's surface. Another point of difference is that a large number of the hurricanes of the West Indies and the typhoons of eastern Asia first pursue a westerly course, which gradually becomes north-westerly, and on arriving at about lat. 30° they recurve and thereafter pursue a course to north-eastwards. The tropical cyclones of the Indian Ocean south of the equator also first pursue a westerly course, which gradually changes to south-west, and often on arriving about lat. 30° recurve to the south-east. Many of the cyclones of India have their origin to westwards of the Nicobar Islands, pursue a course to north-westward, and die out in the valley of the Ganges; and, similarly, a considerable number of the cyclones of the West Indies pursue a westerly course through the Gulf of Mexico, and several die out in the States.

The most dreadful attendant on tropical cyclones is the storm-wave, caused by the in-blowing winds and the low pressure of the centre of the storm. When this wave is unusually high and is hurled forward on a low-lying coast at high water it becomes one of the most destructive agents known. The Bakarganj cyclone of October 31, 1876, was accompanied by a wave which flooded the low grounds to the east of the delta of the Ganges to heights varying from 10 to 45 feet, by which more than 100,000 human beings perished.

Tracks of Cyclones of North America, Atlantic, and Europe.—In the *Physical Atlas of the Atlantic Ocean*, issued under the direction of Dr Neumayer of the Deutsche Seewarte, plate 28 shows by shadings the mean positions of the centres of cyclones and by lines their mean tracks. The following are the regions where the lowest barometer of storms has been most frequently found:—the region to west-south-west of the lakes of the United States; the Gulf of St Lawrence; mid-Atlantic about lat. 35° long. 52°; to the south-west of Greenland; to the south-west of Iceland, which is by far the most important of the whole; to the south-west of the Lofoten Isles; the region embracing Denmark, the south of Scandinavia, and Finland; and, as secondary centres of frequency, the south of the British Islands, Corsica and part of Italy adjoining, and the north-east of the Adriatic. The great importance of these centres, where the lowest barometers are most frequently found, consists in the indication they give of the precise regions either where many storms originate or where they are either retarded or arrested in their course. As regards the origin of storms, the centre west of the Mississippi is the region where most of the United States storms originate, the centre in the Gulf of St Lawrence is where many of the great Atlantic storms have their origin, and the centres in mid-Atlantic and to the south-west of Iceland are the regions where the storms of north-western Europe chiefly originate. The centres on the south-west of Greenland, the Lofoten Isles, Denmark, and the south of the British Islands, all appear to suggest that storms are retarded in their onward courses on coming up against large masses of land,—which may, in part at least, be occasioned by the heavy rainfalls that mark these parts of their courses.

Of all storm tracks the most frequently taken is that by the storms of the United States, which pursue an easterly course through the lakes to the Gulf of St Lawrence. A considerable number of storms follow a course from Nova Scotia to Davis Straits; but the larger number take a north-easterly course through the Atlantic towards Iceland and thence past the north of Norway. Among the less frequent but important tracks are these:—from near New Orleans along the east coast of the States towards Nova Scotia; from mid-Atlantic to south of Ireland and thence through France to the north of the Mediterranean; and from the Atlantic about lat. 42° long. 40° in a north-easterly course quite outside but at no great distance from the British Islands, and thence towards the North Cape. Of the tracks more immediately affecting British weather are one from Iceland in a south-easterly direction through the North Sea and Germany, and four tracks which start from near Scilly:—(1) to the south-east as already described; (2) eastward through the north of Germany; (3) north-east to Christiania; and (4) north through Ireland and the Hebrides. These are the storm tracks which chiefly give the United Kingdom its easterly and northerly winds.

The Inclination of Winds to the Isobars.—The vorticose motion of the winds in a cyclone towards and in upon the centre has been already pointed out. One of the more important practical problems of meteorology is the determination of the angle of inclination of the winds to the isobars in the different segments of the cyclone, not only from the application of the results of the inquiry to the theory of storms but also to practical navigation. The first real contribution to the subject, based on accurate measurements, was made by Clement Ley in 1873.[1] From the observations made at fifteen places in north-west Europe examined by him he showed that the winds incline from districts of higher towards those of lower pressure at a mean angle of 20° 51′; that the inclination is much greater at inland than at well-exposed stations on the coast, the respective angles being 28° 53′ and 12° 49′; and that the greatest inclinations are with S.E. winds. Then follow S.W., N.E., and N.W. winds, the last showing the least inclination. Whipple has recently compared the winds at Kew with the barometric gradients for the five years ending 1879, with the result that the greatest inclination is 63° with S.E. winds, the least 35° with N.E. winds, and the mean for all winds 52°.

As regards the open sea, Captain Toynbee has shown, from a careful investigation of the great Atlantic storm of August 24, 1873, that the mean angle of inclination calculated from one hundred and eight observations was 29°, the mean at the three selected epochs examined varying from 25° to 31°.

Barometric Gradient and Velocity of the Wind.—In inquiring into the relation of the velocity of the wind to the barometric gradient, it is necessary to have some definite information as to the increase of the velocity with height above the ground. Stevenson recently made observations on this point on winds varying from 2 to 44 miles an hour from the surface up to a height of 50 feet, from which he has drawn the following conclusions:—(1) the spaces passed over in the same time by the wind increase with height above the ground; (2) the curves traced out by these variations of velocity from 15 to 50 feet high coincide most nearly with parabolas (fig. 20)

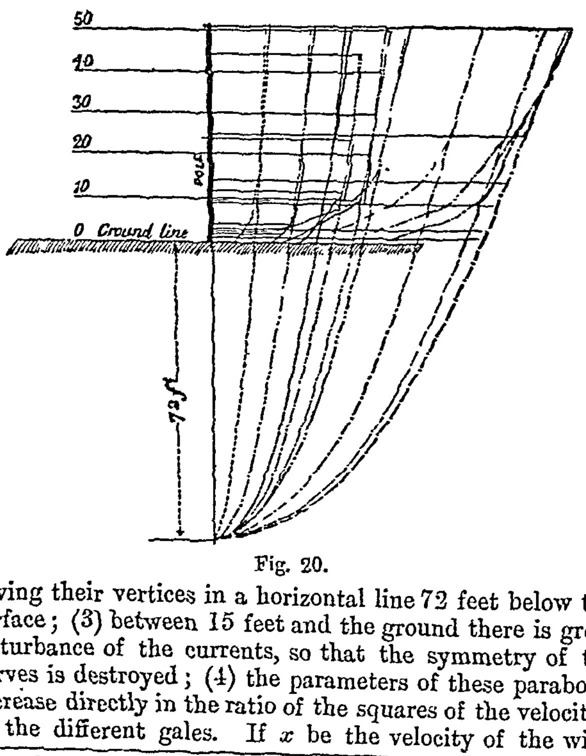

Fig. 20.

having their vertices in a horizontal line 72 feet below the surface; (3) between 15 feet and the ground there is great disturbance of the currents, so that the symmetry of the curves is destroyed; (4) the parameters of these parabolas increase directly in the ratio of the squares of the velocities of the different gales. If x be the velocity of the wind at height H above the ground, the parameter of the corresponding parabola is $x^2/(H+72)$; and as x varies the parameter will vary as x^2 or as the square of the velocity of the gale. It follows that, to render wind observations comparable, it is necessary that anemometers be placed at one uniform height above the ground, and that standard height not lower than 15 feet above the surface. It is very desirable that the inquiry were prosecuted up to a height of 100 feet; and it is of the utmost importance that the variation in the diurnal velocity be at the same time determined at different heights from 15 feet upwards.

Stevenson also made wind observations on the Calton Hill, Arthur's Seat, and the Pentland Hills, in the vicinity of Edinburgh, up to a height of 1600 feet above sea-level. It is from observations made at stations on knolls and peaks at different heights above the sea, and at different heights above the surfaces of their summits, that the problem of the variation of the wind's velocity at different heights with the same barometric gradient can be ascertained. In carrying the inquiry to considerable heights, the results cease to be comparable with those obtained at lower levels, unless in those cases where neighbouring heights are available for data from which the barometric gradient at the observed height can be calculated. The results of observations as to the velocity of atmospheric currents at very great elevations in the atmosphere deduced from the apparent movements of the higher clouds are altogether incomparable with the winds near the surface of the earth, for these among other reasons:—the heights of the clouds can be at best but imperfectly ascertained; the motion of the clouds, particularly the higher clouds, may be only apparent, it being sometimes difficult to distinguish between the formation and dissolution of clouds and their motion; and above all, since the higher clouds are usually the accompaniments of the greater weather changes, their movements are the result of barometric gradients towards a knowledge of which we are absolutely powerless to take a single step.

As regards surface winds, Clement Ley in 1881, and Whipple more recently and with greater fulness, have calculated the mean wind velocities for twelve gradients,—the gradients being derived from the daily weather charts of the Meteorological Office for the five years 1875 to 1879 at 8 A.M., and the corresponding wind data being obtained from the hourly readings of the Kew anemograph. The barometric gradient is for 15 nautical miles, and the following are the velocities for the twelve gradients on the mean of the year:—

Gradient. inch.	Velocity. miles.	Gradient. inch.	Velocity. miles.
0·002	5·0	0·017	15·0
0·005	7·0	0·020	16·5
0·007	7·5	0·022	19·1
0·010	9·2	0·025	22·0
0·012	11·6	0·027	22·0
0·015	12·6	0·030	25·5

The influence of season is very strongly marked. The velocities for the same gradients in order are—October to December, 12·5 miles; July to September, 12·6 miles; January to March, 14·8 miles; and April to June, 17·2 miles. From those observations of Whipple it follows that during the six months when the temperature is falling the velocity for the same gradients is least, while the velocity is greatest during the six months when the temperature is rising, and absolutely greatest during the three months ending June, when the greater part of the annual increase of temperature occurs. It is evident that the observed increase in the velocity of the wind for the same gradients is to be referred to the same cause that brings about the diurnal increase in the wind's velocity, viz., the wind blowing over a warmer surface than itself.

[1] *Journal Scottish Meteorological Society*, vol. iv. p. 66.

Whipple has also sorted the winds according to the eight points of the compass, with results of the greatest interest. If N.W., N., N.E., and E. winds be grouped together as polar, and S.E., S., S.W., and W. winds as equatorial winds, the mean hourly velocity of the polar winds, for the same gradients, is 1·1 miles in excess of the equatorial winds. Now, since polar winds pass into lower latitudes, the surface of the earth over which they blow is warmer, whereas the surface is colder than the equatorial winds which blow over it. It follows that the increased velocity of polar winds is referable to the same conditions which result in the diurnal increase in the wind's velocity and the greater velocity for the same gradients of winds when the annual temperature is rising, since in all these cases the winds blow over a surface of a higher temperature than their own.

It is evident from these considerations that for the development of the law of the relation of the wind's velocity to the barometric gradient with an exactness sufficient to warrant us in expressing that relation in a general mathematical formula much yet remains to be done. In truth, as regards the various formulæ submitted by Ferrel, Mohn, Hann, Everett, and others, we have no choice but to allow the justness of Strachan's criticism (*Modern Meteorology*, p. 98) that the theoretical values furnished by the formulæ do not accord with the actual values, and that therefore a satisfactory formula is yet to be found. Ere such a formula need be looked for, the conditions must be fulfilled for the preliminary work of supplying the observational data required. The "Challenger" observations prove that, with gradients substantially the same, the velocity of the wind is greater on the open sea than near land; and we have seen that the velocity varies with the hour of the day, and generally is increased as the temperature of the surface rises above that of the air blowing over it, and diminished as the temperature of the surface falls below that of the air. It is evident that observations on the open sea will afford data for the simplest solution of the problem; but on land the diurnal, seasonal, and nonperiodic changes of temperature greatly complicate the problem, and render necessary for its solution observations specially designed for the purpose. It is not easy to see how these can be obtained but by carrying out the plan proposed in 1875 by Stevenson of establishing strings of well-equipped meteorological stations planted sufficiently close that the barometric gradients may be determined within the limits of accuracy required. Observations made twelve times daily for a year, at stations so arranged, would supply the observational data for the solution of this fundamental problem in meteorology. Till some such proposal be carried out, the problem remains unsolved, for barometric gradients based on the widely separated existing stations are too uncertain and rough and the wind observations are wanting in that comparability which alone can satisfy the inquiry.

Weather and Weather Maps.—Weather is the state of the air at any time as respects heat, moisture, wind, rain, cloud, and electricity; and a change of weather implies a change in one or more of these conditions. Of these changes the most important as regards human interests are those which refer to temperature, wind, and rain; and, as these are intimately bound up with the distribution of atmospheric pressure, the latter truly furnishes the key to weather changes.

These relations are well shown by the International Monthly Weather Maps issued by the United States Signal Service. Of these that for December 1878 is a striking example. This month was characterized over the globe by unusually abnormal weather. A line drawn from Texas to Newfoundland, across the Atlantic, the north of France, and Germany, thence round to south-east, through the Black Sea, the Caucasus, India, the East India Islands, and Australia to the South Island of New Zealand, passes through a broad and extended region where pressure was throughout considerably below the mean of December, and this low pressure was still further deepened in various regions along the line. Another line passing from Australia, through the Philippine Islands, Japan, Manchuria, Behring's Strait, and Alaska, also marks out an extensive region where pressure was uninterruptedly below the mean.

On the other hand, pressure was above the average, and generally largely so, over the United States to west of longitude 90°, over Greenland, Iceland, the Faroes, Shetland, and a large portion of the Old Continent bounded by a line drawn from Lapland round by Lake Balkhash, Canton, Peking, to the upper reaches of the Lena. Another area of high pressure extended from Syria, through Egypt and East Africa, to the Cape; and part of a third area of high pressure appeared in the North Island of New Zealand. As regards North America, the greatest excess of pressure, 0·196 inch above the mean, occurred in the Columbia Valley, from which it gradually fell on proceeding eastward to a defect from the average of 0·146 inch near Lake Champlain and to northward, rising again to near the mean on the north of Nova Scotia. To the north and north-east exceedingly high pressures for these regions and the season prevailed, being 0·635 inch above the mean in Iceland, 0·500 in the south of Greenland, and at the three stations in West Greenland, proceeding northward, 0·115, 0·102, and 0·316 inch.

West Greenland being thus on the west side of the region of high pressure which occupied the northern part of the Atlantic, and on the north-east side of the area of low pressure in the States and Canada, strong south winds set in over that coast, and the temperature at the four Greenland stations, proceeding from south to north, rose to 1°·1, 8°·8, 12°·1, and 11°·4 above the means. As the centre of lowest pressure was in the valley of the St Lawrence about Montreal, strong northerly and westerly winds predominated to westward and southward, where consequently temperature was below the average, the deficiency at Chicago and St Louis being 9°·5; and, winds being easterly and northerly in California, the temperature there was also under the mean. On the other hand, in the New England States, the greater part of the Dominion of Canada, and West Greenland temperature was above the average. Pressure was much higher at St Michael's, Alaska, than to south-westward at St Paul's, Behring's Strait, and hence, while temperature at St Paul's was 2°·9 below the normal, it was 12°·0 above it at St Michael's, where strongly southerly winds ruled. With these strong contrasts of pressure, America presented contrasts at least as striking in the distribution of the temperature. Along the south of Lake Michigan the November temperature was 13°·7 above the normal, whilst the December temperature was 9°·5 below it, the difference there between the two consecutive months being thus 23°·2.

As regards Europe, Iceland was on the east side of the patch of high pressure which overspread the north of the Atlantic, and hence northerly winds prevailed there and temperature fell 7°·2 below the mean, presenting thus a marked contrast to the high temperature of West Greenland at the time. In Europe, the area of lowest pressure occupied the southern shores of the North Sea, extending thence, though in a less pronounced form, to south-eastward. Hence over the whole of western Europe winds were N.E., N., and in the south-west of Europe W.; and hence everywhere from the North Cape to the north of Italy temperature was below the normal, in some places greatly so, the deficiency being 10°·4 in the south of Norway and 12°·2 in the south of Scotland. On the other hand, on the east side of this area of low pressure winds were southerly and temperature consequently high. In some localities in Russia the excess above the mean was 15°·0, and over a large proportion of European Russia the excess was not less than 9°·0. This region of high temperature extended eastward into Siberia as far as the Irtish, being coterminous with the western half of the anticyclonic region of high pressure which overspread central Siberia. But over the eastern portion of the anticyclone northerly winds prevailed, with the inevitable accompaniment of low temperatures over the whole of Eastern Asia, the deficiency at Nertchinsk on the upper Amur being 6°·8. Here again, just as in America, Greenland, and Iceland, places with atmospheric pressure equally high presented the strongest contrasts of temperature. Thus at Bogoslovsk, on the Ural Mountains, pressure was 0·211 inch and at Nertchinsk 0·154 inch above the normals, but Bogoslovsk on the west side of the high pressure area had a temperature 15°·0 above, whilst at Nertchinsk it was 6°·8 below the average.

At this time of the year the mean pressure falls to the minimum in Australia, but during December 1878 the usually low pressure was still further diminished. Pressure at this season also falls to the annual minimum in the North Pacific and North Atlantic, and it has been seen that the low pressure of these regions was likewise still further diminished. But in the case of the Atlantic it was attended with a most important difference. The centre of lowest pressure, usually located to the south-west of Iceland, was removed some hundreds of miles to the south-east, and an unwonted development of extraordinarily high pressure appeared to the north

ward, overspreading the extensive region of Baffin's Bay, Greenland, Iceland, Faroes, and Shetland. It was to this region of high pressure, particularly in its relations to the low-pressure region to the south-east of it, that *the extreme severity of the weather in the* British Islands at the time was due. Now this high-pressure region was intimately connected with, and doubtless occasioned directly by, upper atmospheric currents from the widely extended region of low pressure to southward, with its large centres of still lower pressure in the North Sea, mid-Atlantic, and United States, where pressures were respectively 0·307, 0·322, and 0·146 inch under the normals. Thus, with the single exception of the high-pressure area about Greenland, the meteorological peculiarities which render December 1878 so memorable over nearly the whole globe arose out of a distribution of the earth's atmosphere essentially the same that obtains at that time of the year, but the usual irregularities in the distribution of the pressure appeared in more pronounced characters.

Taking the all-important bearings of these areas of high and low pressure on weather and climate into consideration, along with the abnormal concentration of aqueous vapour over extensive regions which they imply, it is evident that, when the meteorologist will be in a position to forecast, on scientific grounds, the weather of the coming season for the British Islands, it is to the Atlantic he will require to look for the data on which the forecast is based.

These questions, which the International Weather Maps of the United States enable us to discuss, are of the first importance in meteorology, whether we consider the amplitude of the atmospheric changes they disclose (these being often so vast as to embrace four continents at one time, besides being profoundly interesting from their direct bearings on the food supplies and commercial intercourse of nations) or regard the larger problems they present, with hints towards their solution, which underlie physical geography, climatology, and other branches of atmospheric physics. The discussion presents the great atmospheric changes as influenced by oceans and continents, including the subordinate but important parts played by mountain ranges, extensive plateaus, and physically well-defined river basins in determining the development, course, and termination of these changes.

Weather Forecasts and Storm Warnings.—It is in tropical and subtropical countries that an isolated observer may, with a close approximation to certainty, predict the approach of gales and hurricanes. In these regions atmospheric pressure and the other meteorological conditions are so constant from day to day that any deviation, even a slight one, from the average of the hour and season in respect of pressure, the direction and strength of the wind, and the direction and amount of cloud, implies the presence of a storm at no great distance. Dr Meldrum has practically worked out this problem at Mauritius with great success. At the Royal Alfred Observatory there the mean pressure at sea-level in January at 9 A.M. is 29·966 inches, from which it falls to 29·904 inches at 4 P.M., then rises to 29·980 inches at 10 P.M., and again falls to 29·927 at 4 A.M. The mean direction of the wind and the diurnal variation, both as regards direction and force, have been stated (p. 125). Suppose then that the barometer is observed to fall after 9 A.M. more rapidly than is due to the usual daily barometric tide, that in the afternoon it does not indicate the second maximum or that it continues to fall instead of rising,—or suppose, in short, any deviation from the mean daily march,—then it is certain that there is somewhere an atmospherical disturbance near enough to Mauritius to influence the pressure. The direction in which the disturbance is from Mauritius is readily known from the wind, and the distance of the storm closely approximated to by noting the rate and amount of the fall of the barometer, in connexion with the changes of the wind and the clouds,—the rate and progressive motion of the storm being known chiefly from the veerings of the wind. For a good many years past notifications have been sent to the daily newspapers when observations show that a storm is not far from the island, stating its position and probable course from day to day. The scheme of storm warnings at Mauritius has been entirely successful, and the result is of great value, since it shows what may be done at an isolated station in the ocean, or what may be done in ships at sea. In this connexion it is not possible to overestimate the importance to seamen of a knowledge of the hourly variations of the barometer and its mean monthly heights over the ocean tracks of commerce.

In passing from Mauritius to the British Islands we pass from a region where the forecasting of storms and weather is simplest and easiest to the region where it is most complex and difficult, particularly for the western districts of these islands. The great difficulty lies in the fact that the British Islands are immediately bounded by the Atlantic to westwards; and, since practically every storm and nearly all weather changes come from that direction, no telegraphic communication of their approach can be received. The Meteorological Office in London has therefore no choice but to base the forecasts on such of the observations telegraphed to the office as experience has shown to be the precursors of storms and other weather changes. The more important of these observations are the falling and rising of the barometer taken in connexion with changes in the direction and force of the wind. Since on the north side of the track of the centre of the storm winds are northerly and easterly and temperature low, and on the south side winds are southerly and westerly and temperature high, one of the most important points to be ascertained is the probable path the centre of the coming storm will take. Though a good deal remains to be accomplished in the development of this phase of storms, yet much has recently been done in this direction by close examination of the changes of pressure in the region of the anticyclone contiguous to the advancing storm and by the changing positions of the rain area near the centre of the cyclone.

As regards Europe, the facility of forecasting storms increases as distance from the west coasts is increased. Thus to the middle and eastern districts of the British Islands, were a day and night watch established in the west, forecasts of almost every storm could be issued, the exceptions being those small cyclones or satellite cyclones, as they are called, originating within the British Islands themselves, which are frequently characterized at once by their severity and by the rapidity of their onward course. In the United States, the system of weather forecasting is perhaps the best in temperate regions,—a result due to the admirable system organized and developed under the direction of the late General Myer, and adequately subsidized by the Government, but above all to the facilities to detect and track the storms in the region where nearly all of them have their origin, to west of the Mississippi, before they advance upon the more thickly peopled States.

Meteorology sustained a heavy loss by the death in 1877 of Leverrier, who was not only the keenest-sighted of physicists but also the prince of organizers of systems of meteorological observation. His last great service to the science was the establishment of a system of observation, by which the propagation of rain, hail, and other weather phenomena could be followed and recorded from commune to commune over France. This scheme for the investigation of the vitally important bearing on the meteorology of a country of a comprehensive observation of its rainfall, hail, and thunderstorms, through numerous observers possessing sound local information, is not only eminently just in science, but is calculated to be attended with the greatest benefits to agricultural and other public interests. The practical advantages of the scheme, it need scarcely

be added, can only be reaped after a very large expenditure of labour and money in organizing a comprehensive parochial scheme of observation, systematically and persistently carried through and discussed.

Further details regarding meteorological phenomena will be found in the articles ATMOSPHERE, BAROMETER, CLIMATE, HYGROMETRY OZONE, RAINGAUGE, SEA, and THERMOMETER. (A. B.)

TERRESTRIAL MAGNETISM.

1. In the preceding portion of this article some account has been given of the influence which the sun and moon exert upon the air, the earth, and the ocean, their strictly tidal effects being left to be separately dealt with. The discussion of the influence of these bodies on what may be termed the movables of the earth will not be complete, however, without embracing an account of the changes which they produce in the earth's magnetism. An account of the earlier magnetic observations has already been given under the heading MAGNETISM, and our task will now be to give in the first place a description of the best and most recent instruments by which the magnetic state of the earth is determined, embracing therein observatory instruments, those adapted for travellers whether by land or by sea, and differential magnetometers. We shall next give a short account of the magnetic system of the earth and of its secular variation; and we shall then investigate the changes connected with terrestrial magnetism depending on the sun and moon. In performing this task we shall be led to conclude that the sun's power is variable, and we shall therefore examine whether this conclusion is likewise borne out by strictly meteorological observations. Finally, we shall venture on remarks embodying a provisional working hypothesis, and our object will be gained if this should be found to suggest certain lines of thought to those interested in the subject which may lead them to examine and discuss the very great mass of observations at present existing.

INSTRUMENTS FOR DETERMINING THE MAGNETIC STATE OF THE EARTH.

(α) *Observatory Instruments.*

2. *Declinometer.*—It is that end of the needle which points to the north magnetic pole of the earth of which the position is invariably noted even when the observation is made in the southern hemisphere. The difference of this position from true geographical north denotes what is called the variation or declination (east or west, of the needle. East is often reckoned negative and west positive. The instrument by which this information is obtained is called the declinometer. The unifilar magnetometer, which is the form of declinometer now used, is described and figured in MAGNETISM, vol. xv. p. 228.

3. *Dip Circle.*—The instrument by which the magnetic dip or inclination is observed contains a thin needle about 3 inches long, the centre of gravity of which coincides as accurately as possible with the axis of motion of the needle. The needle has two axles consisting of two very fine cylinders of hard steel standing at right angles to the plane of the needle, and great attention must be paid to keep these axles in a state of perfect polish and dryness. By means of these the needle can oscillate freely on two horizontal agate rounded edges, the one axle lying on the one edge and the other axle on the other. If the centre of gravity coincides exactly with the axis of motion, and if there be no adhesion or friction between the axles and the agate edges, the needle must settle into such a position that its magnetic axis lies in the true line of dip.

The position of the ends of the needle is read by means of two microscopes which move round on a cross piece carrying verniers. To view the position of the lower end of the needle we move round the lower microscope until the cross wire in its field of view (extending in the line between the two microscopes) symmetrically cuts the extremity of the needle. The lower vernier is then read. The same process is repeated for the upper vernier, and the mean of the two readings is taken. This mean will accurately denote the position of the needle if the circle is properly set.

The sources of error in a dip observation are—(1) a want of symmetry in mass, the centre of gravity of the needle not being coincident with the axis of motion; (2) the vertical circle being erroneously set; (3) a want of symmetry in magnetism, the magnetic axis not being coincident with the axis of figure; (4) eccentricity, the axis of rotation of the needle not passing through the centre of the circle; (5) friction and adhesion of the axles as they rest on their agate supports. This last source of error is guarded against by taking great care of the axles, and by inserting them gently into a piece of cork before each observation; the agate supports ought also to be rubbed with cork. Then, again, when the needle has assumed its position, before reading it is gently raised by means of a lifter, the handle for turning which is shown in the figure towards the right. It is then gently lowered, and this process is repeated until no apparent change of position is produced by the operation.

4. We shall now describe a complete dip observation. The first point is to make the needle to swing in the plane of the magnetic meridian. In order to accomplish this, after levelling the instrument, the verniers are set for 90°, that is, for a vertical position of the needle. The whole instrument is now turned round its horizontal circle until the extremities of the needle are bisected by the wires of the two microscopes, and the position of the vernier of the horizontal circle is then read. The needle is next reversed so that the microscope shall view its other flat side; it is made vertical as before, and the position of the horizontal circle read once more. Next the face of the instrument is turned round 180°, and the same two operations repeated. We have thus four readings of the horizontal circle, and if we take the mean of these we shall have ascertained with sufficient accuracy the position of that plane for which the needle is vertical. Now this plane must be removed 90° from the magnetic meridian, for in such a plane the horizontal magnetic force of the earth would have no resolved portion acting in the plane of the needle's motion, so that the needle would practically be under the sole influence of the vertical magnetic force, and would therefore point in a vertical direction. By this means therefore we obtain the magnetic meridian, and thus know the plane in which we ought to swing the needle. The needle must now be read in the following positions:—(α) face of instrument east—face of needle to face of instrument; (β) face of instrument west—face of needle to face of instrument; (γ) face of instrument west—back of needle to face of instrument; (δ) face of instrument east—back of needle to face of instrument. Finally, the poles of the needle must be reversed, by rubbing them with powerful bar magnets in a direction opposite to that in which they were previously rubbed, and four observations taken corresponding to the above. The mean of the eight observations so obtained will give us the true dip.

The turning round of the face of the instrument from east to west is made to counteract any error due to erroneous setting of the vertical circle. The reversal of the face of the needle is made to counteract any error due to the centre of gravity of the needle not being quite coincident in the direction of the needle's breadth with its axis of motion, and likewise any error due to want of symmetry of the magnetic axis. The correction for eccentricity is made by reading both ends of the needle. Finally, the reversing of the poles of the needle is intended to counteract any error due to the centre of gravity of the needle not being coincident in the direction of the needle's length with its axis of motion.

Dr Joule[1] has suggested a modification of the dip circle in which the needle is hung on fine threads on which it rolls instead of resting on agate supports.

5. *Horizontal Force Magnetometer.*—The theory of the instrument for determining the horizontal component of the earth's magnetic force has already been given in the article MAGNETISM, vol. xv. pp. 228 *sq.*, and the instrument is shown in two forms, *ibid.*, figs. 28 and 29. The corrections necessary for accurate results are explained in a paper by G. M. Whipple (*Proc. Roy. Soc.*, 1877).

(β) *Instruments adapted for Travellers by Land.*

6. *Declinometer.*—For travellers by land the unifilar instrument (§ 2), mounted on a tripod stand and duly levelled, is perhaps the most accurate kind of declinometer.

For this purpose it is furnished with a transit mirror by means of which an image of the sun may be thrown into the field of view of the telescope, and—the geographical position of the station as well as the apparent time of the observation being known—an azimuth thus determined. In order that such an observation may succeed, the following points must receive attention.

In the first place the axis of the mirror must be horizontal; the adjustment for this is made by means of a riding level. Secondly, the normal to the plane of the mirror must be perpendicular to the axis. The adjustment for this is made by a screw attached to the back of the mirror. Take some object sufficiently elevated and reflect it into the telescope, getting the object bisected by the wire of the telescope. Then reverse the mirror in its bearings. If the object remains still bisected by the wire no correction requires to be made, but if not the screw at the back of the mirror must be moved until the object is in precisely the same position in both observations. Thirdly, the line of collimation of the telescope must be perpendicular to the plane of the mirror. In order to obtain this there is a collimating eye-piece attached to the telescope by which the sun's light may be made to illuminate the cross wires. Now turn the transit mirror until the reflection of the illuminated cross wires coincides with the wires themselves, in which case the line of collimation of the telescope must be perpendicular to the plane of the mirror. When this correction has been once made, note the circle reading of a small vernier which moves with the mirror and always set the mirror so as to give this reading.

[1] *Proc. Lit. and Phil. Society, Manchester*, vol. viii. p. 171.

By these means an accurate reading of the sun's bearing may be made; and, the position of the place and the time of observation being known, there are tables which enable the azimuth to be at once determined.

7. *Lloyd's Method of Determining the Total Force.*—While the dip circle and the horizontal force magnetometer may be used by travellers in addition to their use as observatory instruments, the Rev. Dr Lloyd has devised a new method of determining the total force. The ordinary method of obtaining this is first to find the dip and the horizontal force, from which the total force can be at once determined by the equation,—total force = horizontal force × secant dip. This method is, however, open to objection in high magnetic latitudes where the horizontal force is very small and the dip approaches 90°. Now in Lloyd's method this objection is overcome. Another circumstance which renders his method peculiarly convenient for high magnetic latitudes, where a traveller's equipment must be kept as light as possible, is the fact that it only requires the addition of two needles to an ordinary dip circle in order to give the required determination. These needles must be carefully kept from contact with other magnets, and their poles never reversed.

Here as before we have two unknown quantities to determine, the one being the magnetic moment of the magnet and the other the total force of the earth. We must, therefore, obtain two results, the one embodying the product of the earth's total force into the magnetic moment of the needle, while the other gives the ratio between these two quantities.

8. In order to determine the former of these, let the needle have a grooved wheel of radius r attached to its axle as in fig. 21, and over this wheel let an accurately known weight W be

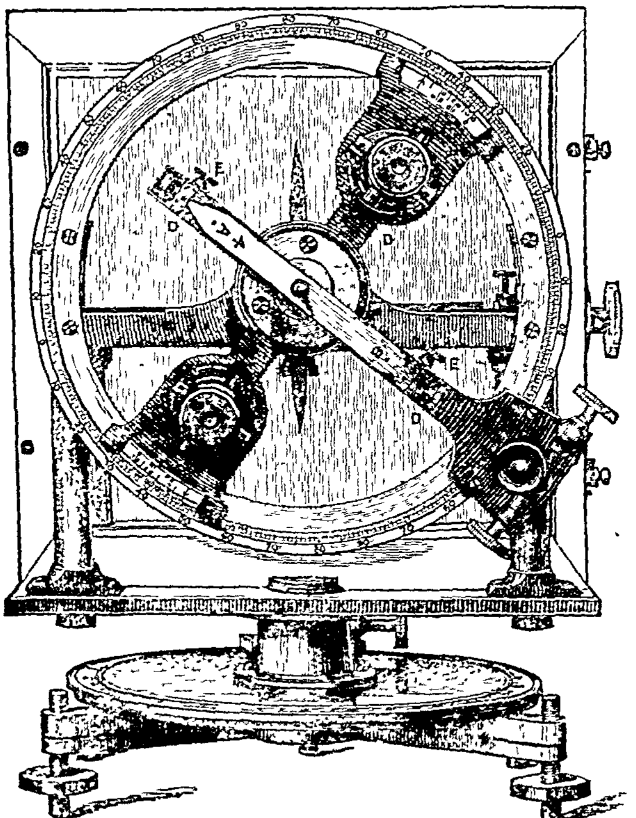

FIG. 21.—Dip Circle.

suspended by means of a very fine silk thread. The best way of doing this is to have a thread with two hooks of precisely equal weight at each end and then attach the preponderating weight W to one of these hooks. When this is done a new position of equilibrium will be taken by the needle. If we suppose that m denotes the magnetic moment of the needle, that i is the angle of dip at the place, and that η denotes the angle which the needle in its deflected tiposition makes with the horizon, the weighting being so made dellet η shall be less than i, then it is clear that the needle has been If we out of its position of equilibrium through an angle $i - \eta$. at the pl..ll this angle u and designate by R the total force we obtain the following equation of equilibrium:—

on the supposit $$m\mathrm{R}\sin u = \mathrm{W}r \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1),$$

that W denotes a c (which is very nearly but not strictly correct) tant force at all latitudes.

9. Next, in order determine the ratio between this needle's force and that of the deflect another substitute th, let it be removed and employed to i its place.

When using it thus as a deflector it should be laid in a frame in an invariable position as in fig. 21. This frame is at right angles to the line between the two microscopes, and as both pieces move together the best plan is to turn the whole round until the deflected needle is visible in the centre of the field of the microscopes, in which position it is of course perpendicular to the deflecting needle. By always keeping to this arrangement we secure an invariable distance between the poles of the two needles. Suppose therefore that we have employed the needle as a deflector in the above manner, and that the deflected needle has thus been made to assume a position denoting an angle η' with the horizon. It has therefore been deflected from its position of equilibrium by an angle $i - \eta'$ (i denoting the dip as before); calling this angle of deflexion u', we obtain the following equation of equilibrium:—

$$\mathrm{R}\sin u' = m\mathrm{U} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2),$$

U being a function depending upon the distance of the needles and on the distribution of free magnetism in them.

10. If we multiply together equations (1) and (2), we obtain

$$\mathrm{R}^2\sin u \sin u' = \mathrm{UW}r \quad . \quad . \quad . \quad . \quad . \quad . \quad (3),$$

in which u, u' are determined by observation, while W and r may be regarded as constants. U is, as we have said, a function depending upon the distance of the two needles and upon the distribution of free magnetism in them.

The magnetic moment of these needles is of course liable to alteration, but if they are carefully guarded from contact with magnets we may imagine that while their intensity alters, becoming weaker for instance, this nevertheless does not sensibly affect the distribution of the free magnetism within them, in which case the function U may be regarded as a constant quantity. The results obtained by this method of Lloyd's fully confirm this hypothesis regarding U; but it is essential that the two additional needles, the deflector and the deflected needle, should have their poles at no time either reversed or disturbed.

Assuming therefore the constancy of the quantity U, its value may be easily determined at any base station where the total force has been determined independently by the ordinary method.

11. Having thus determined the value of U, or at once of UWr (which we may call c), let us carry our instrument to a different station and make the requisite observations. We thus obtain

$$\mathrm{R} = \sqrt{\frac{c}{\sin u \sin u'}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (4).$$

As this method is specially adapted for high latitudes, the dip circle employed (fig. 21) ought to be one for which the agate supports are horizontal, so as to admit of the needle being visible when the dip is nearly equal to 90°. It will also be noticed that, if the deflecting needle have the same temperature when it is used in equation (1) which it has when used in equation (2), then m in the one case is strictly equal to m in the other, and thus no temperature correction is rendered necessary.

12. A slight modification of the method now described is sometimes adopted. Instead of employing separate weights, which may be easily lost, two small holes are bored in the deflecting needle near each end. The one of these is filled with a suitably heavy brass peg when the observations are to be made in the higher magnetic latitudes of the northern hemisphere, and the other is filled in a similar manner when the observations are to be made near the southern pole. In this case therefore we must readjust the instrument as we pass from the one hemisphere to the other. A slight change must be made in the formula when this method is adopted, for it is clear that the weight will not now act always at the same constant leverage. If the weight be called W and its leverage when the needle is horizontal r, we shall have to modify equation (1) as follows:—

$$m\mathrm{R}\sin u = \mathrm{W}r\cos\eta \quad . \quad . \quad . \quad . \quad . \quad . \quad (5).$$

Equation (2) will, however, remain unaltered, and hence equation (3) will become

$$\mathrm{R}^2\sin u \sin u' = \mathrm{UW}r\cos\eta \quad . \quad . \quad . \quad . \quad . \quad (6).$$

If the quantity UWr be determined at the base station and called c', we shall have

$$\mathrm{R} = \sqrt{\frac{c'\cos\eta}{\sin u \sin u'}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (7).$$

(γ) *Instruments adapted for Travellers by Sea.*

13. *Azimuth Compass.*—At sea the declination is generally observed by means of an azimuth compass invented by Kater. This is exhibited in fig. 22. It consists of a magnet with a graduated compass card attached to it. At the side of the instrument opposite the eye there is a frame which projects upwards from the plane of the instrument in a nearly vertical direction, and this frame contains a wide rectangular slit cut into two parts by a wire extending lengthwise. The eye-piece is opposite this frame, and the observer is supposed to point the instrument in such a

manner that the wire above mentioned shall bisect the sun's visible disk. There is a totally reflecting glass prism which throws into the eye-piece an image of the scale of the graduated card, so that the observer, having first bisected the sun's disk by the wire, must next read the division of the scale which is in the middle of the field of view. He thus obtains a reading of the sun's position; let us call this 100°. From this, knowing the geographical position of his station and the time of the observation, he may deduce an azimuth; let us imagine that this is 70° W. Thus a reading of 100° corresponds to a position 70° W. Suppose next that the instrument is so adjusted that when the magnetic axis of the magnet is between the eye-piece and the wire the reading is 0°. It is thus clear that the magnetic meridian is 100° removed from the position 70° W. Let us imagine that the instrument is so graduated that this denotes a position 30° E. We have thus obtained the magnetic declination. If the vessel be at rest the plan generally adopted is to take the reading of the sun when rising and also when setting; a mean between the two will give that which corresponds to a geographical meridian.

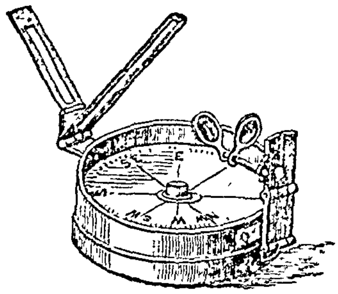

FIG. 22.—Azimuth Compass.

14. *Fox's Dip Circle.*—This instrument, contrived by Robert Were Fox, is more especially useful for observations at sea. In this case it must be placed on a gimball stand and duly levelled before commencing the observation. The following are the peculiarities of this instrument:—(1) the needles have two fine pivots or axles which are inserted into jewelled sockets; (2) in order to avoid parallax there are two graduated circles, the one farther from the eye than the other, and when reading the needle the eye is to be so placed that precisely the same reading shall be given by both circles,—the true position of the needle being thus obtained; (3) there is a rubber made of bone or ivory and roughened, the object of which is to rub a prolongation of the socket on the back of the instrument,—the friction which this rubbing causes enabling the needle to find its true position; (4) to avoid as much as possible all effects due to friction and adhesion, the entire socket arrangement may be turned round. The axles of the needle are thus compelled to be in contact with a different set of particles. Another way of varying the suspension is to use a magnetic deflecting arrangement attached to the back of the apparatus. Suppose that a reading of the position of the needle so deflected is now taken. Next reverse the position of the deflecting arrangement, which is done by turning a movable circle attached to this arrangement 180° round; let the position of the needle be again read. On the hypothesis that the needle is equally deflected on opposite sides of its true position in these two observations, the mean reading will give the true dip. The principle of the method of observing with this circle is precisely the same as that already described for observations on shore with an ordinary inclinometer.

15. *Fox's Intensity Arrangement* is merely a modification of that introduced by Lloyd, and already described in § 7.[1]

(δ) *Differential Magnetometers and Self-Recording Magnetographs.*

16. In addition to determinations at fixed intervals of time, it is a point of much interest and importance to keep a continuous record of all the magnetic changes which take place at a few selected stations. This is accomplished by means of differential magnetometers. It is, however, necessary to continue to use absolute instruments side by side with differential magnetometers, because the latter (with the exception of the declination instrument) are badly fitted for recording changes of long period, such as the secular changes of the horizontal and the vertical force. The reason of this will presently be seen.

17. Early in the history of such instruments it was found that hourly observations were exceedingly laborious, and attempts were made to construct a set of self-recording magnetometers. The first set of such instruments which were brought into systematic operation were those devised and constructed by the late Charles Brooke, which have been at continuous work in the Greenwich Observatory since 1848. In 1857 John Welsh devised a fresh set of self-recording instruments, and introduced them into the Kew Observatory. These, with certain slight modifications, have formed the type of instruments supplied to a large number of magnetic observatories all over the globe.

18. As we cannot conveniently record changes of dip by a differential instrument, changes of vertical force are measured instead by a balance or vertical force magnetometer. We have thus in a differential system, whether adapted to eye observation or to continuous photographic registration, three instruments, namely, the declination, the horizontal force, and the vertical force magnetometers or magnetographs as the case may be. The most recently constructed instruments are adapted both for photographic registration and for eye observation through a telescope. The advantage of eye observations is that we see what is taking place at the very moment of its occurrence, whereas we only obtain the photographic record some time after the changes to which it relates have actually happened.

We shall therefore describe—(α) the three instruments of the Kew pattern as adapted to eye observations; (β) these instruments as adapted to continuous registration by photography; (γ) the method of determining their scale coefficients; (δ) the method of determining the temperature coefficients of the force instruments.

19. *Kew Instruments—Eye Observations.*—Fig. 23 shows us these instruments arranged in the relative positions recommended by Lloyd so as magnetically to interfere with one another as little as possible. We are supposed to be viewing the whole from the south. No. 1 to the right is the declination instrument, No. 2 that for the horizontal force, and No. 3 in the distance behind the centre pillar (No. 4) the vertical force magnetometer. Figs. 24, 25, 26 give us the details of these three instruments in the same order as above. Connected with each instrument there is a circular mirror, or rather two semicircular mirrors, made of perfectly plane glass. One semicircular half of each mirror is attached to the magnet and moves with it, while the other half is firmly attached to the marble slab. Each magnet is enclosed in a gun-metal case with windows of perfectly plane glass; each gun-metal case is covered with a glass shade; and the whole is air-tight, and capable of exhaustion. Each magnet too is provided with a copper damper with the view of checking its oscillations. In fig. 23 will be seen two pillars of smaller size. The right-hand pillar carries a telescope, with a scale attached, to record the position of the declination magnet. The scale is reflected from the semicircular mirror moving with the magnet, and the position of this reflected scale as viewed in the telescope indicates the position of the magnet. The optical arrangement for the other instruments is similar, except that the vertical force mirror has a horizontal and not a vertical axis. The telescopes for viewing the force instruments are attached to the left-hand pillar of smaller size.

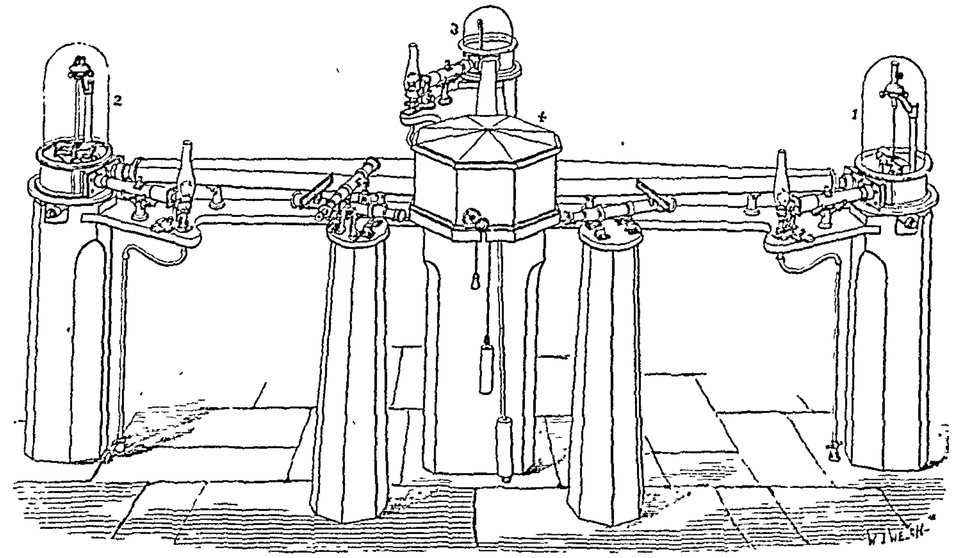

FIG. 23.—Kew Instruments.

20. The *Declinometer*[2] (fig. 24) consists of a magnet about 5 inches long suspended by a silk thread freed from torsion as completely as

[1] A great deal of detailed information regarding instruments for absolute determination and the methods of observing with them is to be found in the *Admiralty Manual of Scientific Inquiry* in an article on "Terrestrial Magnetism," by Sabine and Welsh. A treatise on *Terrestrial and Cosmical Magnetism*, by E. Walker, may likewise be consulted with much advantage.

[2] For a detailed account of the Kew magnetographs, see *British Association Reports*, 1859.

possible. To keep the state of the thread constant the glass shade should be rendered air-tight, and should contain some substance for absorbing moisture, such as chloride of calcium. It is clear that if the state of the thread remains the same, and if the position of the magnetic axis of the magnet does not change, this instrument should record faithfully the various changes of declination.

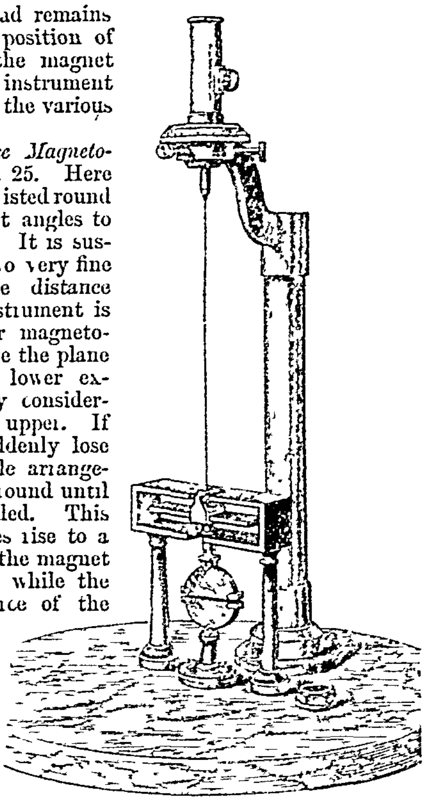

Fig. 24.—Declinometer.

The *Horizontal Force Magnetometer* is exhibited in fig. 25. Here the magnet[1] has been twisted round into a position at right angles to the magnetic meridian. It is suspended by means of two very fine steel wires some little distance apart, and thus the instrument is often called the bifilar magnetometer. These wires have the plane passing through their lower extremities differing very considerably from that of their upper. If the magnet should suddenly lose its magnetism the whole arrangement would be twisted round until the two planes coincided. This difference of plane gives rise to a couple tending to twist the magnet round in one direction while the horizontal magnetic force of the earth constitutes an equal and opposite couple, the two couples keeping the magnet in equilibrium. The couple depending upon the bifilar arrangement may for the present be regarded as constant, that depending on the horizontal force of the earth as variable. If the latter increase or diminish, the magnet will be slightly twisted round in one direction or the other.

In the *Vertical Force Magnetometer* (fig. 26), the magnet is balanced by means of a knife-edge resting on an agate plane. By means of two screws working horizontally and vertically the centre of gravity may be thrown to either side of the point of suspension, or it may be raised or lowered and the sensibility of the magnet when balanced thereby increased or diminished. These screws are so arranged that there is a preponderance of weight towards the south side of the magnet. This is neutralized partly by the magnetic force tending to pull the north end down and partly by a slip of brass standing out horizontally towards the north side. Let us suppose the system to be in equilibrium at a certain temperature; if the temperature rise (since brass expands more than steel), the leverage of the weight at the north side will increase more than that of the weight at the south. There will thus be a slight preponderance towards the north, and this may be arranged so as to neutralize to a great extent the decrease in the magnetic moment which an increase of temperature produces.

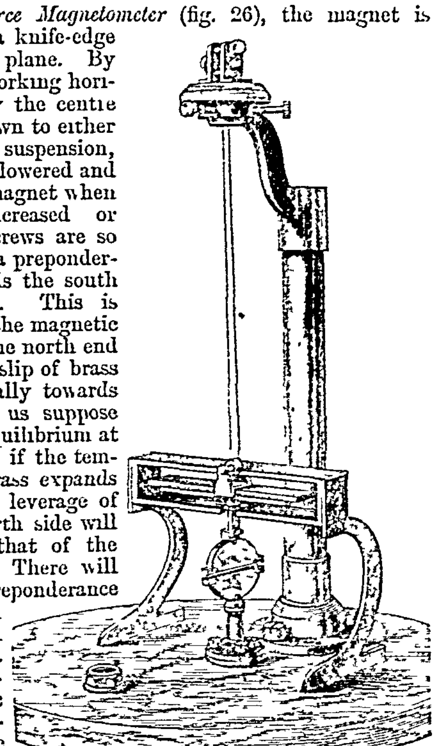

Fig. 25.—Horizontal Force Magnetometer.

21. *Magnetographs.*—The arrangement by means of which these instruments are converted into self-recording magnetographs is very simple. In fig. 23 we see a gas flame burning behind a vertical slit and placed endwise in order to render its light more intense. The light from this illuminated slit passes through a lens, and being reflected from the mirror of the declination magnet throws an image of the slit upon some sensitized paper in the central box. To speak more properly, two images are thrown, one reflected from the upper and movable half and the other from the fixed half of the mirror. The sensitive paper is wrapped round a horizontal cylinder (fig. 27), and the two images are therefore thrown upon different parts of this cylinder. But before reaching the cylinder these two images are by means of a hemicylindrical lens (shown in fig. 27) crushed up into two dots of light. The cylinder moves round regularly by clock-work once in twenty-four hours, and hence the course on the moving paper of the dot of light which comes from the fixed half-mirror will be a straight line, while that of the dot from the moving half-mirror will be a curved line depending on the motions of the magnet. When the paper is developed these lines appear black.

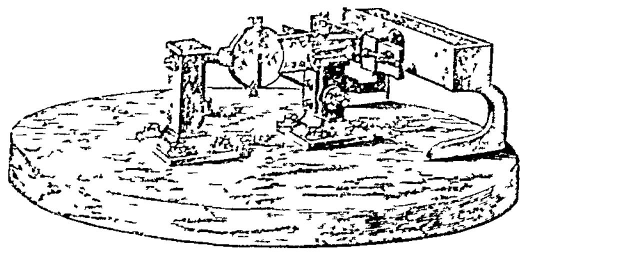

Fig. 26.—Vertical Force Magnetometer.

The arrangement for the horizontal force instrument is precisely similar to that for the declinometer; for the vertical force it is somewhat different, the illuminated slit being horizontal and not vertical, while the mirror oscillates on a horizontal axis and not on a vertical one; the hemicylindrical lens too and the cylinder are vertical and not horizontal. It was found necessary to put the plane of motion of the vertical force magnet 15° out of the magnetic meridian for the following reason. The axes of the telescopes are respectively 30° inclined to the tubes which go from the magnetometers to the central box, and hence had the vertical force magnet swung in the magnetic meridian it would have been necessary to place the mirror inclined at the angle of 15° to the axis of motion of the magnet. This was tried, but it was found that in this position of the mirror the correction for temperature was so excessive that the instrument became a thermometer and not a magnetometer. The mirror was therefore put in a plane passing through the axis of motion of the needle, the needle being made to move in a plane inclined 15° to the magnetic meridian.

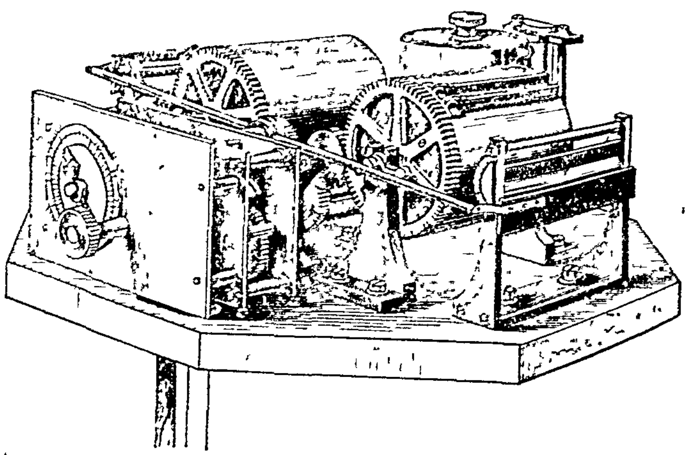

Fig. 27.—Magnetograph.

22. *Scale Coefficients of Differential Instruments.*—It is necessary to know the value of one division of the scale in the magnetometer or of one inch difference in the ordinate of the curve impressed on the photographic paper in the magnetograph. In the declination instrument it is only necessary to obtain the angular deviation corresponding to one division, and this may be done at once by a series of measurements. In the horizontal and vertical force instruments we wish to obtain the value of one division in parts of force. There is more than one method by which this can be accomplished, but that of John Allan Broun is probably the simplest, and it is, we believe, the one adopted at most of the various observatories possessing self-recording instruments. It is given in the *British Association Reports*, 1859.

23. *Temperature Coefficients of Differential Force Instruments.*—Broun has devoted a great deal of attention to the subject of these coefficients, and has come to the conclusion that the best and most unobjectionable method of determining them is to

[1] All the magnets are of the same size.

compare the instrumental readings on days when the temperature is high with the readings on days when the temperature is low.

24. By differential instruments the components of a force affecting the magnet are determined in three directions at right angles to each other. It does not, however, follow that this force is entirely due to changes in the magnetism of the earth. We know that certain forces connected with the sun affect the earth's magnetism, and on certain occasions at least these forces manifest themselves as currents in the upper regions of the atmosphere and in the crust of the earth. Now such currents will have a direct effect upon the needle as well as an indirect effect through the changes which they may produce in the magnetism of the earth. The total influence on the needle will therefore be made up of these two elements, the one denoting the direct influence on the needle of the disturbing force, and the other the indirect influence through the change produced in the earth's magnetism. No attempt has yet been made to separate the action of these two elements.

25. Self-recording instruments after the Kew pattern have been supplied to observatories at the following places:—

Batavia.	Mauritius.
Coimbra (Portugal).	Kolaba (Bombay).
Lisbon.	Vienna.
St Petersburg.	Zi Ka Wei (China).
Florence.	San Fernando (Spain).
Stonyhurst.	Potsdam.
Utrecht (declination only).	Brussels.
Melbourne.	Nice.

There are also self-recording magnetographs of other patterns at Toronto, Montsouris (Paris), Greenwich, Wilhelmshaven (?), Cape Horn, and Havana (?).

We understand that Professor W. G. Adams is at present engaged in making a comparison of simultaneous curves from various stations of these lists.[1]

Magnetic Poles of the Earth—Secular Variation.

26. *Magnetic Poles of the Earth.*—In the article MAGNETISM it has been shown that Dr Gilbert of Colchester had at a very early period grasped the important truth that the earth is a magnet, a truth which was afterwards mathematically demonstrated by Gauss. It was reserved for Halley, the contemporary of Newton, to show that the earth must be regarded as having two poles in the northern and two poles also in the southern hemisphere, so that, unlike ordinary magnets, its magnetic system has four poles altogether. Before proceeding further it will be desirable to state what it was that Halley actually did and what are the conclusions to be derived from his investigations. It has been remarked by Professor Stokes that, while in an ordinary bar magnet we may practically regard the pole as having a physical reality and as being the cause of well-known attractions and repulsions, we are not entitled *a priori* to assume that a point of maximum force in a large spherical magnet like the earth must necessarily be the seat of attractions and repulsions after the same manner as the pole of an ordinary bar magnet. It is to be determined by observation to what extent the earth actually preserves an analogy to an ordinary magnet. Now Halley's conclusions were derived from the pointing of the declination needle, since in his day there were no observations possible on total magnetic force. He argued that there are two points or poles in the northern hemisphere to which the needle appears to be attracted, one in the upper region of America and one above Siberia. So far this conclusion is hardly anything more than a formal one derived from the grouping together of observations. He asserted that these would be as they are known to be if we imagine two such poles or foci of force each exercising a causal influence on the magnetic needle. And the justification of Halley's way of regarding the earth is found in the fact that when force observations came to be made two such foci of force were actually found to exist. We do not, however, mean to imply that these foci have causal properties exactly similar to the poles of a bar magnet, for this is not the case.

In order to exhibit the process of reasoning which led Halley to his conclusion, let us first imagine that the earth has only a single pole or force-focus in the northern hemisphere, and that this is coincident with its geographical pole; then, assuming that this pole has a causative influence on the needle's declination, we should expect all needles to point everywhere due north. If, however, this pole be not coincident with the north pole of the earth, let us draw a meridian circle passing through the magnetic pole and complete it round the earth so as to divide the earth into two halves. At all points in this meridian circle the needle might be expected to point due north, while in the one half of the earth so divided it should point to the east and in the other half to the west of true north. In the next place let us imagine that the earth has two north magnetic poles or foci of equal strength, both being at the same latitude, while their difference in longitude is 180°, and let us draw a complete circle of meridian passing through these poles (fig. 28). Let us start from a point in this circle under one of these poles and pursue our journey eastwards along a circle of latitude. At first the needle will point due north. As we move eastwards the needle will point westwards to the pole we are leaving until we come to a region half-way between the two poles, where it will be equally solicited by each, and will therefore again point due north. Let us call the space we have travelled over since we set out A. As we proceed the needle will now be under the predominant influence of the second pole to our right, and will therefore point to the east until we arrive at the meridian under the second pole. This second space which we have travelled over let us call B. As we proceed we pass through a space C where the needle again points to the west until being once more equally influenced by the two poles it will point due north. After this we pass through a space D of easterly variation until we arrive once more at the point from which we started.

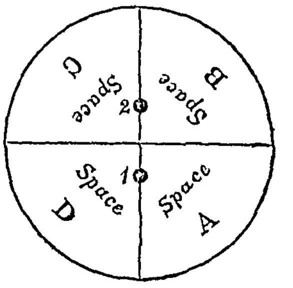

Fig. 28.

Thus there are now four spaces instead of two, and these are shown in fig. 28, where the centre of the circle represents the north geographical pole of the earth, and its circumference the equator. If pole 2 be inferior in power to pole 1 the spaces B and C will be smaller in size than A and D.

27. This last is an arrangement of things that agrees very well with the results of observation, if we add that the two poles are not precisely 180° removed from one another in longitude. Fig. 30[2] represents lines of equal magnetic variation in 1882. There are two lines extending throughout both hemispheres at all points of which there is no variation, and also an oval-shaped district in the northern hemisphere throughout all points in the circumference of which we have no variation. These facts are inconsistent with the hypothesis of a single pole, but they are quite consistent with that of two poles or foci of force, one in northern America and the other in northern Asia, the former being stronger than the latter. In order to see this let us take our stand at the great line of no variation which passes through North America and travel eastwards. We are just south of the American pole or focus, while the Asiatic pole or focus is nearly 180° off, and hence the needle points due north. As we proceed eastwards we leave the American or strongest pole to the westward of us, and hence we have a region of west variation which we have agreed to call A. As we begin to approach the eastern side of Europe we get nearer the Asiatic pole or focus, and at length the line of no variation is reached, the tendency of the American pole to pull the needle to the west being balanced by the tendency of the Asiatic pole to pull it to the east. After this, easterly variation predominates throughout a region B until at length we come to a point in the western boundary of the oval where we may imagine ourselves to be directly south of the Asiatic pole, while the American pole is nearly 180° distant; once more the needle points due north. As we still travel eastwards we leave the Asiatic pole, which is now the predominant one, to our left, and hence we have here a region C of westerly declination. At length we come to the eastern boundary of the oval, where the tendency of the Asiatic pole to pull the needle to the west is balanced by the tendency of the American or stronger pole (acting now towards the right) to pull it to the east, so that we have once more a point of no variation. After this the American pole predominates, and we have a large region D of easterly variation until we travel round once more to the point from which we started.

28. This train of argument receives, as we have already mentioned, corroboration from the fact that in the map of total force we perceive two foci of maximum force, one in northern America and the other in northern Asia, that in America being the strongest. This evidence was not, however, in existence at the time of Halley, and his hypothesis of two poles does the greater credit to his sagacity, inasmuch as he had to deduce it from a comparatively small number of observations of declination and dip, those of force being altogether wanting.

29. We have hitherto spoken of two poles or, more properly, *foci of maximum force*, the positions of which are of course best pointed out in fig. 29; but we have seen that the existence of such

[1] We are indebted to Mr Gordon—and to his publishers Messrs Sampson Low & Co., who have obtained them for us—for the sketches of the instruments for absolute determinations, with the exception of that of Kater's compass, for which we are indebted to Mr J. J. Hicks. For the sketch of the self-recording magnetographs together and in detail we are indebted to the Kew committee and to Mr G. M. Whipple, director of the Kew Observatory.

[2] We are indebted for the admirable charts given in figs. 29–32 to the kindness of the hydrographer, Captain Sir Frederick Evans, who, in order to save time, allowed us to make use of the information he had embodied even before it was officially published, and who likewise placed his plates at our disposal.

foci was first conjectured from the behaviour of the lines of variation or declination. Now it will be noticed by looking at the variation map (fig. 30) that all the lines of equal magnetic variation appear to converge to a point in the extreme north of the American continent. This point is not, however, coincident with the chief *focus of force*, which lies decidedly to its *south*; but it is no doubt coincident with the point denoting a dip of 90°, the locality of which may be inferred from the map of magnetic dip (fig. 31), and it is likewise no doubt *coincident* with the position of a zero of horizontal force which may be inferred from the map of horizontal force (fig. 32). Thus we have a point to the extreme north of America which has the following properties:—(1) the various lines of declination converge to it; (2) the needle points vertically downwards at it; and (3) the horizontal force vanishes at it. At this

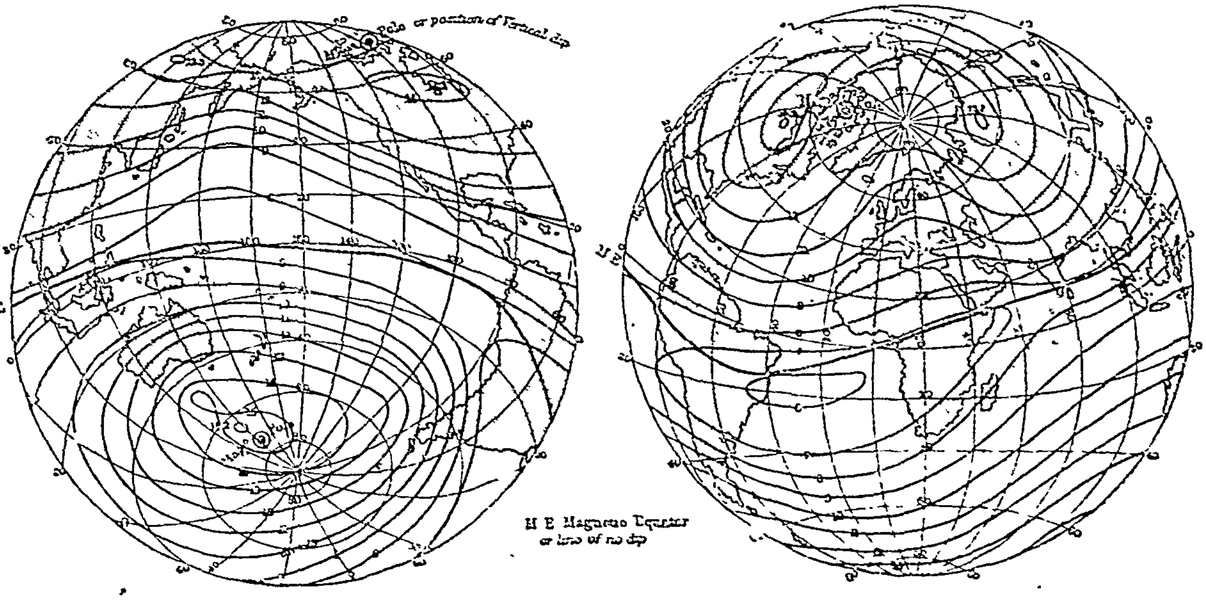

FIG. 29.—The Earth's Magnetism as shown by the Distribution of Lines of Equal Total Force, in Absolute Measure (British miles), with the Position of the Magnetic Poles and Equator,—approximately for 1875.

point therefore the horizontally balanced needle, having no horizontal force acting upon it, will point in any direction.

This point is, strictly speaking, the *pole of verticity*, but, inasmuch as there is only one such point in each hemisphere, these may for convenience sake be termed the magnetic poles, so that we speak of two centres or foci of maximum force and one pole in each hemisphere.

In the northern hemisphere Sir Frederick Evans[1] assumes the stronger or American focus to be in 52° N. and 90° W., and the weaker or Siberian focus in 70° N. and 115° E. In the southern hemisphere he assumes the position of the stronger focus to be 65° S. and 140° E., and of the weaker focus probably 50° S. and 130° E., these being thus not far separated from each other or from the magnetic pole. The nearness together of the southern foci is prob-

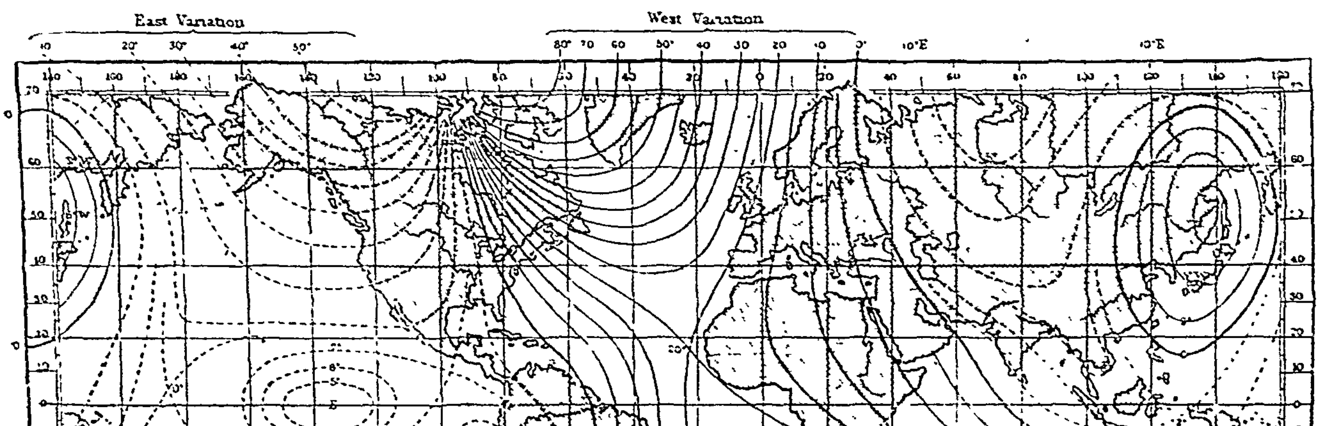

FIG. 30.—Lines of Equal Magnetic Variation, 1882.

ably the reason why the total force is greater at the southern than it is at the northern foci.

The magnetic pole (of verticity) in the northern hemisphere was reached by Sir James Ross in 1831. The position of vertical dip was observed by him to be 70° 5′ N. and 96° 43′ W. The magnetic pole (of verticity) in the southern hemisphere was nearly attained by the same navigator in a voyage made in 1839-43. Its position is probably 73½° S. and 147½° E.

The line of no dip is called the *magnetic* or *dip equator*—its position is given in figs. 29 and 31. The line connecting all the

[1] *Elementary Manual for the Deviation of the Compass in Iron Ships.*

points where the magnetic intensity is least is called the *dynamic equator*. It coincides very nearly with the dip equator.

30. *Secular Variation.*—The earth then as a magnet must be supposed to have two sets of centres of force. We shall next attempt to show that these centres cannot be regarded as constant both in position and intensity.

It should be premised that, while there is no well-established evidence to show that either the pole of verticity or the centre of force to the north of America has perceptibly changed its place, there is, on the other hand, very strong evidence to show that we have a change of place on the part of the Siberian focus and also on the part of its analogue in the southern hemisphere.

Table I. (p. 166), given by Gilpin (*Phil. Trans.*, 1806),[1] exhibits the change in the position of the needle in Great Britain from

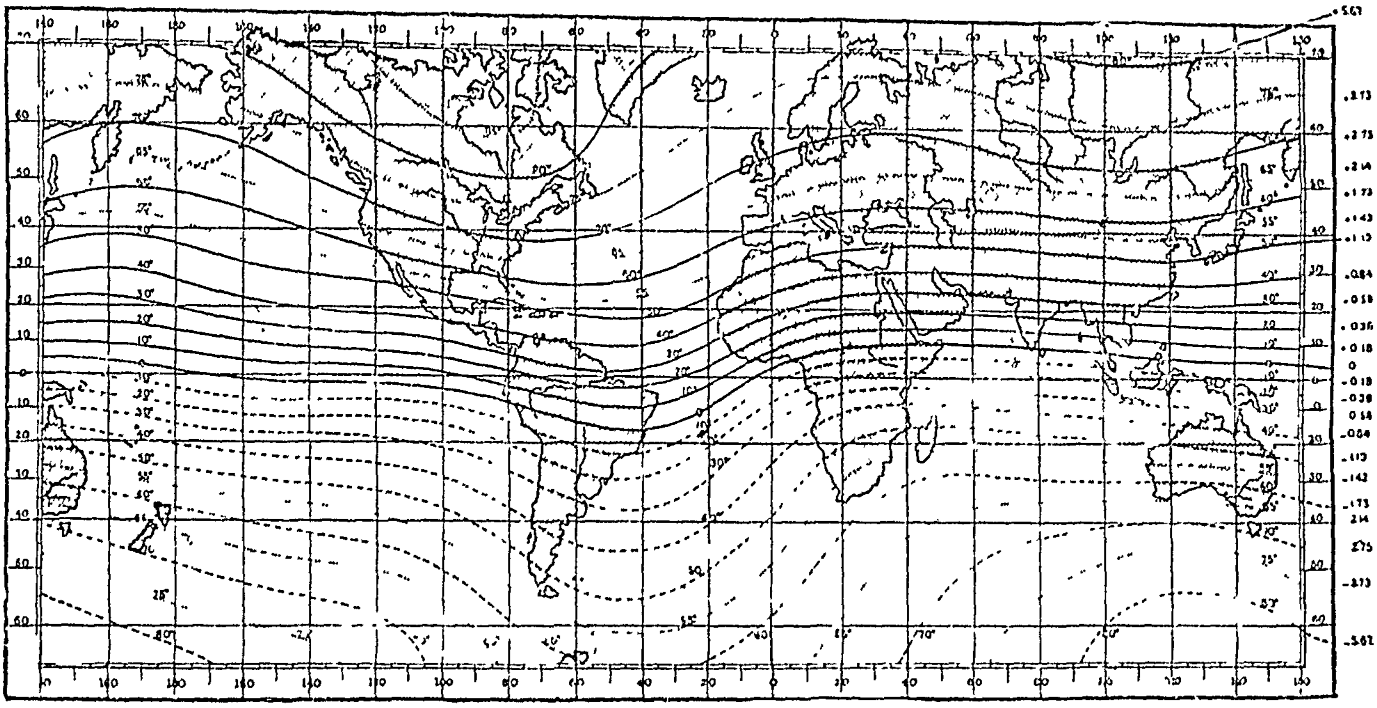

FIG. 31.—Lines of Equal Magnetic Dip, 1882.

the earliest observations up to the beginning of the present century.

31. Between the dates recorded in this table the needle has been pointing more and more to the west, which implies either a relative increase in the power of the American as compared to the Siberian focus, or a motion of the Siberian focus from west to east. On the first supposition the lines to the eastward of the Siberian focus—for instance, the line of no variation depending on a balance between it and the American focus—should be drawn in towards it, or they should travel westwards; but if the latter supposition is true, or this focus has been moving eastwards while retaining its force, the lines to the east of it should be found moving eastwards also. There is strong evidence that the latter is the case, and that in the northern hemisphere there has been a long continued progression

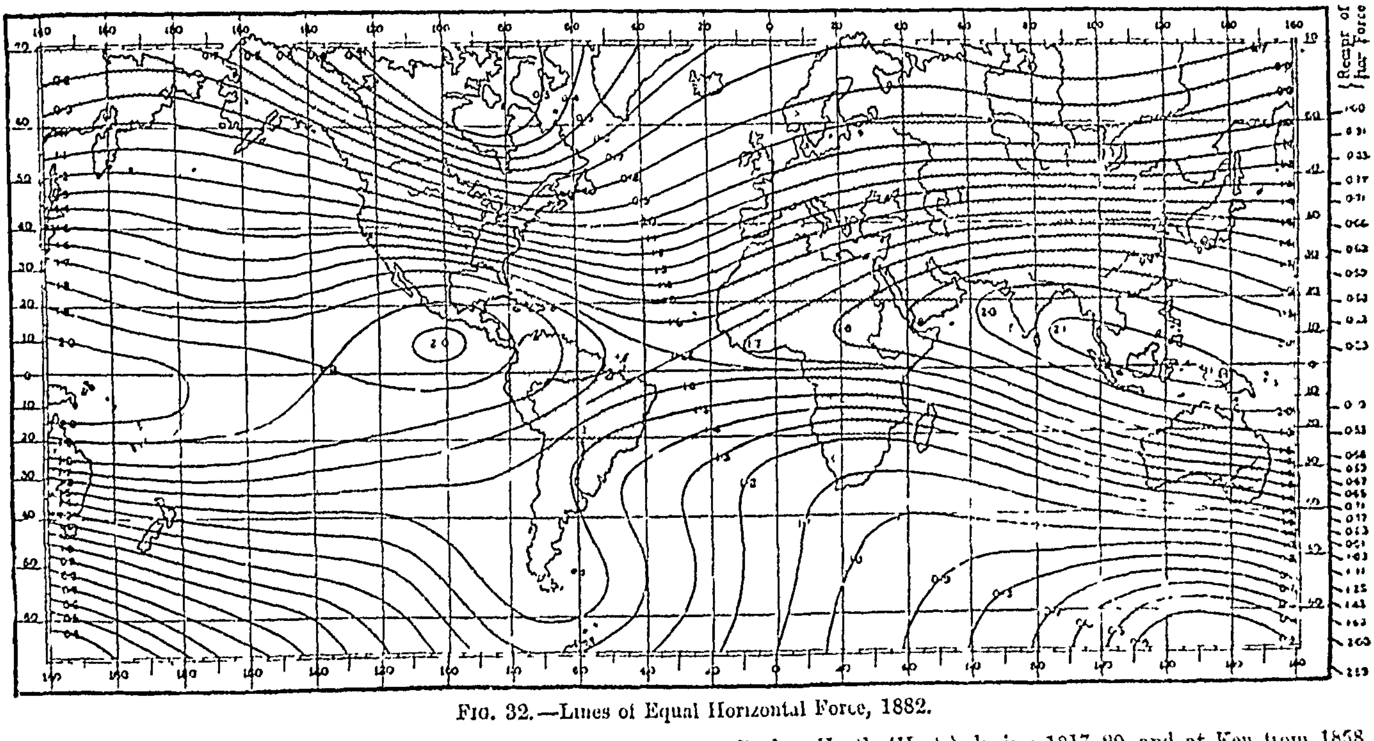

FIG. 32.—Lines of Equal Horizontal Force, 1882.

to the eastwards of the system of magnetic lines on both sides of the Siberian focus. In the southern hemisphere also we have proof that the analogous focus has been travelling, not from west to east, but from east to west.

32. There is some reason to believe that the eastward motion of the Siberian focus has been recently reversed, and that it is now going from east to west. Table II. shows the declination observed at Bushey Heath (Herts) during 1817–20, and at Kew from 1858 to 1882.

It would appear from Table II. that the maximum westerly declination was reached in 1818, and that the needle has since that date been travelling eastwards. A similar change has taken place

[1] Taken from Walker's *Magnetism*.

for the secular change by imagining a solid globe or *terella*,[1] concentric with the earth but rotating independently of the external shell and having a slightly different period of rotation,—the shell having two poles and the terella two others. While continuing to admire Halley's sagacity, we shall not now be disposed to allow such a constitution of the interior of the earth, but will rather be led to look to some external influence as the cause of the secular variation.

While we have strong evidence that the Siberian focus has changed its position, we cannot assert that the American focus has been absolutely stationary, or that neither focus has experienced any changes of force. On these points we must be content to be guided by observation alone.

34. It has been supposed by some magneticians that it is possible to compute with something like certainty the particulars of the motions of the magnetic foci. Hansteen more especially (1811–19) computed both the geographical positions and probable periods of revolution of this dual system of foci of force round the terrestrial pole. Sir Frederick Evans has discussed in connexion with the subject all the most recent observations,[2] and points out two objections to any such theory as that of Hansteen, viz., (1) that, while a magnetic turning point has been reached in certain regions, there are large portions of the earth in which this change has not yet been accomplished, and (2) that in certain districts of the earth very great changes in force have taken place. "If we turn," he says, "to the continent of South America and its adjacent seas, we shall find a diminution of the intensity of the earth's force now going on in a remarkable degree. An examination of the recent observations made by the 'Challenger' officers at Valparaiso and Monte Video, compared with those made by preceding observers, shows that within half a century the whole force has respectively diminished one-sixth and one-seventh,—at the Falkland Islands one-ninth." On the whole, while there is strong evidence that the Siberian focus has until recently been travelling eastwards, and its analogue westwards, and evidence less conclusive that recently a turning point in this motion has been reached, we are disposed to think with Sir Frederick Evans that a formal theory like that of Hansteen does not agree with recent observations. We shall revert to this subject.

35. In Tables III. and IV. certain yearly values of declination, dip, and horizontal force are given for various stations.

Inequalities in or connected with Terrestrial Magnetism depending on the Sun.

36. As there is a marked likeness between the ways in which the sun dominates over the two great divisions of terrestrial phenomena, meteorology and magnetism, let us endeavour to describe the sun's effect upon the latter by referring to its influence on the former, the chief peculiarities of which are well known to all. We find that the temperature of the air at a given station is subject to a diurnal fluctuation having its minimum value shortly before sunrise and its maximum early in the afternoon. We find likewise that the mean temperature for the day, as well as the amplitude of this diurnal oscillation, depends upon the season of the year, both being greatest about midsummer and least about midwinter. Now, if this were the only manifestation of solar influence upon this particular element, it would be possible to predict the temperature for any hour of any day once the mean temperature, the diurnal variation of temperature, and the modification of these for different seasons of the year had been well ascertained. But this amount of regularity is very far from taking place,—the march of temperature being frequently interrupted, cloaked, perhaps even reversed, by the advent of peculiar weather. Thus we may have very cold weather in midsummer and very warm weather in midwinter, or we may have a very cold afternoon and a very warm early morning, by which means the ordinary conditions of temperature will be completely reversed. In like manner weather interferes even to a greater extent with the diurnal oscillation of the atmospheric pressure, so that, in British latitudes at least, it is only possible to obtain this correctly by means of a long series of observations.

Weather, however, does not consist of a perfectly lawless interference with periodical phenomena, but is subject to laws of its own, some of which we are beginning to discover. Sometimes weather may exalt or depress the diurnal fluctuation of temperature without otherwise affecting its character; but sometimes too the turning-points and the general appearance of this fluctuation are greatly influenced by peculiar weather.

37. Now it is believed that we have something of this kind in those fluctuations depending on the sun to which the elements of terrestrial magnetism are subject. Let us take the declination as the most easily studied of the three magnetic elements, and suppose that we are engaged in considering the traces denoting the fluctuations of declination as derived from a set of self-recording magnetographs in Great Britain. Here we shall at once be able to recognize in an unmistakable manner the diurnal variation depending upon the position of the sun, in virtue of which a freely-suspended magnetic needle reaches the easterly extreme of its range about eight in the morning, and the westerly about two in the afternoon. We shall likewise perceive that the range of this diurnal fluctuation is greatest at midsummer and least at midwinter. In fine, the characteristics of this fluctuation, depending as they do upon the hour of the day and the season of the year, are not very different from those exhibited in the diurnal fluctuation of atmospheric temperature. But, however thoroughly we may have ascertained the mean declination and its diurnal oscillation, as well as the modifications of these depending on the season of the year, we shall nevertheless find it impossible to predict the exact position of a freely-suspended magnet at any moment of a particular day. Here then too we have something which may be called magnetic weather, and which interferes with the regular progress of the systematic fluctuations of the magnet. Magnetic weather has, like its meteorological analogue, a set of laws of its own, some of which we are beginning to find out. Sometimes magnetic weather may exalt or depress the diurnal fluctuation of declination without affecting its character, but it is imagined that at other times the turning points and general appearance of this fluctuation may be greatly influenced by peculiar magnetic weather.

38. There is, however, a kind of magnetic change which, so far as we know at present, is not analogous to anything in meteorology, and introduces an additional element of complexity in any attempt to analyse the fluctuations of terrestrial magnetism. We mean the well-known magnetic disturbances or storms which occur simultaneously in places very widely apart. Under these circumstances it becomes a question how we can best deal in a practical manner with this complicated system of things.

We do not think that with our present knowledge any better system can be adopted than that first introduced by Sir Edward Sabine in his discussion of the results of the colonial magnetic observatories. Suppose that we have hourly magnetic observations at a station, then first of all we should arrange these into monthly groups—each hour by itself. We should then reject as disturbed observations all those which differ by more than a certain amount from their respective normals of the same month and hour,—the normals being the hourly means in each month after the exclusion of all the disturbed observations. This method enables us, by its exclusion of disturbances, to ascertain with much accuracy the true form of the solar-diurnal variation of the magnetic elements at a given place corresponding to every month of every year, provided only that the observations are sufficiently numerous. On the other hand it will probably fail in accurately giving us the variations from day to day of the ranges of these diurnal fluctuations caused by the advent of peculiar magnetic weather,—inasmuch as the records of the extreme effects of such weather will probably be cut off from the undisturbed observations and reckoned among the disturbances.

For instance, it is known that the solar influence on terrestrial magnetism varies from year to year, and it is suspected that there are also short-period fluctuations of solar influence. It would not, however, be a safe proceeding to attempt to estimate numerically this last-mentioned element of fluctuation by taking the successive diurnal ranges of those observations at any station, reckoned as undisturbed, by the above process, and plotting them as successive ordinates of a curve, and then supposing that this curve would give us a true graphical representation of solar changes. It would rather probably represent such changes with the tops and bottoms of the larger fluctuations cut off. But if the undisturbed observations fail in this respect we can hardly be wrong in supposing that there has been eliminated from them, as far as possible, all influence due to magnetic storms, and hence that they will afford us a much better means of estimating small fluctuations, such, for instance, as those due to the moon, than we could have had without their aid.

Finally, with regard to that portion of the observations selected as disturbed, we are probably not certain that every such observation represents a true disturbance, or that the absolute times of occurrence of the various observations selected as disturbed at one station will be the same as those at another. Nevertheless Sir Edward Sabine has shown that at the Kew Observatory certain laws of disturbance deduced from the whole body of observations selected as disturbed are closely reproduced when this selection is made on a narrower basis—ninety-five days of prominent disturbance being alone taken. With these prefatory remarks we shall now proceed to discuss the diurnal inequality of terrestrial magnetism.

39. *Total Diurnal Inequality Defined.*—It will be seen further on that disturbed as well as undisturbed observations are subject to a diurnal variation, but these two variations are different, and the name *diurnal inequality* is generally given to the compound variation which is the joint resultant of the two. *Solar-diurnal variation* is that portion of the compound inequality which refers to undisturbed observations, while that which refers to disturbances has received the name of *disturbance-diurnal variation*. It would appear that in the United Kingdom, and perhaps throughout Europe, the total diurnal inequality is not very greatly different either in character or range from its most important component the solar-diurnal variation, at least so far as the

[1] See Walker's *Terrestrial and Cosmical Magnetism*, where the subject is well discussed.
[2] In his lecture to the Royal Geographical Society, March 11, 1878.

declination is concerned. When the diurnal oscillation of a freely-suspended magnet was first observed, the subject of magnetic disturbances was not understood, and the early individual determinations which have been handed down to us are not such as to justify the expenditure of any very great labour upon them for the purpose of separating the disturbed from the undisturbed observations. Inasmuch, however, as the total diurnal inequality of declination (which is in reality the element given by these early observations) does not greatly differ from the solar-diurnal variation, we may with much justice and little risk of error give the history of these early observations in connexion with that of the solar-diurnal variation of declination, which is by far the best known, and perhaps the most important, of all the various magnetic changes produced by solar influence.

40. *Solar-Diurnal Variation of Declination.*—Graham, an instrument maker of London, discovered in 1722 that a freely-suspended magnetic needle is subject to a diurnal oscillation of definite character.[1] The next observer was Canton, who in 1756 began a series of nearly four thousand observations, which he communicated to the Royal Society on December 13, 1759, and from which he concludes that the range of the diurnal variation is greater in summer than in winter. Macdonald's observations at Fort Marlborough in Sumatra in 1795 (*Phil. Trans.*, 1796), and Duperrey's in the tropics in 1825, were perhaps the first that might lead us to conclude that the amplitude of the diurnal oscillations of the needle is less in the tropics than in middle latitudes, and that the motion of the needle in the southern hemisphere is in the opposite direction to that in which it moves in the northern hemisphere at the same hour.

41. *Semiannual Inequality.*[2]—The existence of these early observations had led some magneticians prematurely to conjecture that there must be a line somewhere near the equator at which there is no horary variation in declination. In 1847 Sabine communicated to the Royal Society the results of five years' observations at St Helena, showing that at that station for the half of the year beginning at the vernal and ending at the autumnal equinox the motion of the needle corresponds nearly to that in the northern hemisphere, whilst for the other half it corresponds nearly to that in the southern hemisphere. Sabine afterwards confirmed and extended his conclusions regarding the semiannual inequality by discussing the results obtained at the various colonial magnetic observatories. More recently, as the result of twelve years' observations at Trevandrum, at an observatory established by the rajah of Travancore, John Allan Broun gave in a very complete form the laws of change of the solar-diurnal variation of magnetic declination near the equator, showing the extinction of the mean movement near the equinox.

42. Perhaps the best way of exhibiting what really takes place is the following, which is that adopted by Sabine.

The mean annual value of the solar-diurnal variation is of what may be called the northerly type in places of middle latitude in the northern hemisphere, and of what may be called the southerly type in places of middle latitude in the southern hemisphere. Now let us take a northern station, and consider the mean form of its solar-diurnal variation for the six months beginning with the vernal equinox. Here we shall have an oscillation of the northerly type with a range greater than the annual range. For these six months, therefore, we may imagine that the annual range has been supplemented by the superposition on it of a variation with a type similar to its own. At the same station, during the other six months, the solar-diurnal variation is less than the mean of the year, as if the annual variation had been depressed by the superposition on it of a variation with a type the opposite of its own, that is to say, with a southerly type. At a station in the southern hemisphere, again, the mean annual form of the solar-diurnal oscillation is of the southerly type, reduced during the six months beginning with the vernal equinox by the superposition on it of a variation of northerly type, and increased during the other six months as if by the superposition of a variation of southerly type. Thus when the sun is north of the equator we may superpose a variation of the northerly type upon both hemispheres, with the effect of increasing the range in the northern hemisphere and diminishing it in the southern; and while the sun is south of the equator we may superpose a variation of the southern type upon both hemispheres, with the effect of diminishing the range in the northern and increasing it in the southern hemisphere.

Near the equator, as at Trevandrum, where Broun made his observations, we find the mean annual value of the solar-diurnal variation to be extremely small, if not altogether evanescent. During the six months beginning with the vernal equinox the type is entirely northerly, while for the remaining six months of the year it is entirely southerly in character. In fine, at this station the solar-diurnal variation changes its character at the equinoxes, at which time we have, as already observed, an extinction of the mean movement,—not indeed an absence of all variation, but rather a variation having an undecided character, which for a few days may be of one type and then of the very opposite. There is movement, but no mean movement.

43. In the following table (V.) the solar-diurnal variation is given for Kew, Trevandrum, and Hobart Town. Of these places the first denotes a station in middle latitude (northern hemisphere), the second an equatorial station, and the third a station in middle latitude (southern hemisphere).

Astronomical Hours.	Kew.			Trevandrum.			Hobart Town.		
	April to Sept.	Oct. to March.	Whole Year.	April to Sept.	Oct. to March.	Whole Year.	April to Sept.	Oct. to March.	Whole Year.
0	−6·15	−4·12	−5·13	−1·30	+0·07	−0·61	+0·35	+2·35	+1·35
1	−7·42	−4·96	−6·19	−1·25	+0·35	−0·45	+2·15	+4·85	+3·50
2	−6·94	−4·67	−5·81	−0·85	+0·56	−0·15	+3·15	+5·95	+4·55
3	−5·21	−3·35	−4·28	−0·35	+0·61	+0·13	+3·30	+5·50	+4·40
4	−3·25	−1·95	−2·60	+0·03	+0·53	+0·28	+2·40	+4·30	+3·35
5	−1·47	−1·05	−1·26	+0·15	+0·33	+0·24	+1·30	+2·70	+2·00
6	−0·32	−0·46	−0·39	+0·05	+0·22	+0·13	+0·75	+1·55	+1·15
7	+0·22	+0·21	+0·22	−0·15	+0·23	+0·04	+0·20	+0·80	+0·50
8	+0·44	+0·92	+0·68	−0·36	+0·19	−0·05	−0·30	+0·30	+0·00
9	+0·52	+1·45	+0·99	−0·28	+0·13	−0·08	−0·85	−0·25	−0·55
10	+0·70	+1·77	+1·24	−0·20	+0·09	−0·06	−1·10	−0·70	−0·90
11	+0·90	+1·84	+1·37	−0·07	+0·10	+0·01	−1·15	−0·85	−1·00
12	+1·19	+1·67	+1·43	+0·07	+0·11	+0·09	−1·10	−0·80	−0·95
13	+1·23	+1·34	+1·29	+0·18	+0·08	+0·13	−0·75	−0·75	−0·75
14	+1·56	+1·22	+1·39	+0·27	+0·02	+0·15	−0·40	−0·70	−0·55
15	+1·93	+1·09	+1·51	+0·29	−0·11	+0·09	−0·15	−0·65	−0·40
16	+2·58	+1·17	+1·88	+0·31	−0·28	+0·02	−0·02	−0·78	−0·40
17	+3·60	+1·43	+2·51	+0·18	−0·45	+0·01	−0·10	−1·40	−0·75
18	+4·59	+1·54	+3·07	+1·02	−0·66	+0·18	−0·23	−2·37	−1·30
19	+5·31	+1·85	+3·58	+1·48	−0·81	+0·32	−0·50	−3·80	−2·15
20	+5·20	+2·40	+3·80	+1·20	−0·72	+0·24	−1·25	−5·25	−3·25
21	+3·57	+2·32	+2·95	+0·47	−0·36	+0·06	−2·10	−5·30	−3·70
22	+0·38	+0·54	+0·46	−0·32	−0·13	−0·22	−2·20	−3·80	−3·00
23	−3·18	−2·18	−2·68	−0·93	−0·07	−0·50	−1·40	−0·80	−1·15

In this table deflexions towards magnetic east are reckoned positive, deflexions towards magnetic west negative. The scale is in minutes of arc.

Also in fig. 33 we have a graphical representation of the solar-diurnal variation for the whole year at these three stations, from which it will be seen that the range at Trevandrum is extremely small, and that the curve for Hobart Town is opposite in appearance to that at Kew.

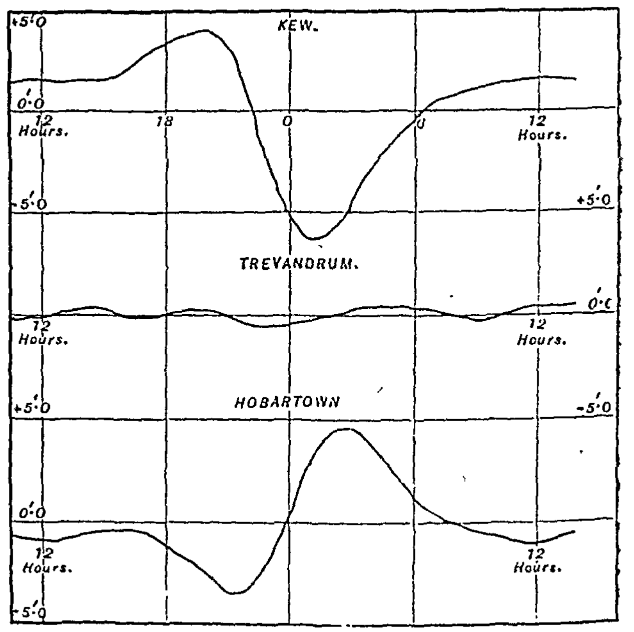

Fig. 33.

Finally, in fig. 34 we have a graphical representation of the semiannual inequality or difference from the whole year's mean of the two half-yearly means of Table V., the one half-year (that with thick lines) commencing at the vernal and the other at the autumnal equinox. It will be seen from this figure that the semiannual inequality is of the same character in both hemispheres, the likeness extending even to its minor peculiarities.

44. *Change from Month to Month.*—Charles Chambers, director of the Kolaba Observatory, Bombay, remarks (*Trans. Roy. Soc.*, December 10, 1868) that "the regular progression from month to month in the diurnal variation is so distinctly shown in the Bombay observations as to lead, on a first inspection, to the supposition that the law of variation is identical throughout the year, the extent only (including a reversal of direction) varying from month to month. But in this respect a different exposition of the character of the variation in different months shows that the first thought would be inaccurate." He then proceeds to discuss

[1] See Walker, *Terrestrial and Cosmical Magnetism.*
[2] This is the name used by Sabine, but its appropriateness may perhaps be questioned.

at length the monthly values of the solar-diurnal variation at Bombay. Broun has likewise (Trevandrum observations) discussed at length the solar-diurnal variation at the Trevandrum Observatory. It would hardly be of service to reproduce here the results of these discussions; but when such analyses become sufficiently

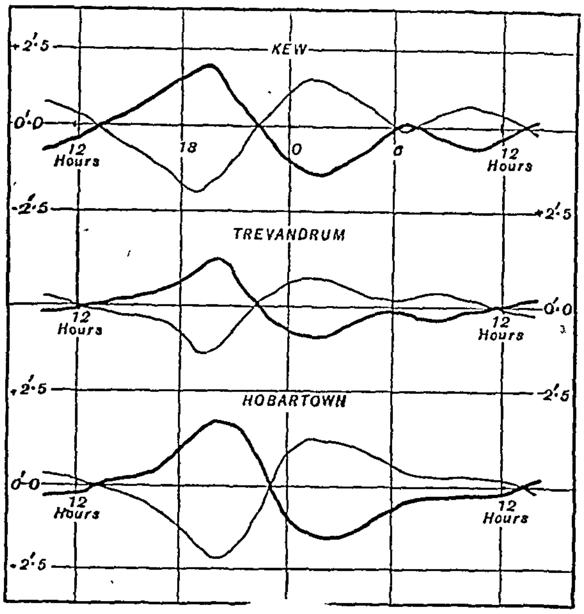

Fig. 34.

extensive they may be expected to throw light upon the cause of the solar-diurnal variation.

In the following table we have mean monthly values of the declination range at the Kew Observatory corresponding to forty-eight points in the year—derived from sixteen years' observations:—

TABLE VI.—*Containing Monthly Means (unit=22'·04) for Forty-eight Points in the Year of the Kew Solar-Diurnal Declination Ranges. Thus January (0) gives the monthly mean of which the middle date is the very commencement of the year, January (1) that for one week after the commencement, and so on.*

	Mean Value.		Mean Value.		Mean Value.
Jan. (0)	·312	May (0)	·593	Sept. (0)	·594
(1)	·323	(1)	581	(1)	·577
(2)	·340	(2)	·573	(2)	554
(3)	·362	(3)	·586	(3)	·532
Feb. (0)	·385	June (0)	·596	Oct. (0)	·513
(1)	·401	(1)	·605	(1)	·496
(2)	·418	(2)	·610	(2)	·478
(3)	·438	(3)	·604	(3)	·463
March (0)	·467	July (0)	·601	Nov. (0)	·445
(1)	·508	(1)	·597	(1)	·418
(2)	·548	(2)	·591	(2)	·389
(3)	·587	(3)	·593	(3)	·360
April (0)	·615	Aug. (0)	·594	Dec. (0)	·340
(1)	·632	(1)	·601	(1)	·322
(2)	·639	(2)	·611	(2)	·308
(3)	·620	(3)	·606	(3)	·308

It will be seen from this table that, while we have a maximum about the summer and a minimum about the winter solstice, we have unmistakable indications of maxima at or about the equinoxes. This does not take place at a tropical station such as Trevandrum.

45. *Behaviour near the Magnetic Pole.*—Figs. 33 and 34 exhibit the most prominent features of the solar-diurnal variation of declination in the extra-tropical regions of the northern hemisphere. If an observer stand over the centre of the needle and look towards the marked end, or that which points to the north, he will perceive a deflexion towards his right hand which will reach its extreme about 8 A.M. and a deflexion towards his left hand which will reach its extreme about 2 P.M. But are these deflexions to the right and left hand of geographical or of magnetical north? This question has been answered by Sabine in his discussion of the results of hourly observations of the magnetic declination at Port Kennedy (*Phil. Trans.*, 1863, p. 660). This station is 72° 0' 49" N. lat. and 94° 19' W. long., and here the marked end of the needle, while it points towards the magnetic pole, points in reality about 35° to the west of south. Now the marked end of the needle when viewed at 8 A.M. is seen at Port Kennedy to have moved to the geographical west but to the magnetical east. It would thus seem that throughout the extra-tropical regions of the northern hemisphere the 8 A.M deflexion of the needle is always towards the magnetic east but not always towards the geographical east, while the deflexion at 2 P.M. will always tend towards the magnetical west but not always towards the geographical west. In fine the oscillations have reference to the north magnetic pole of the earth and not to the north geographical pole. No observations of this nature have been made in the southern hemisphere.

46. *Long-Period Inequalities of Declination Range.*—It was first observed by Lamont that the yearly values of the diurnal range of magnetic declination at Munich presented signs of a long-period variation. In 1852 Sabine (*Phil. Trans.*, 1852, p. 103) showed that this inequality corresponded in its progress with that of the frequency of black spots on the surface of the sun.

The existence of black spots on the disk of the sun was long ago known to the Chinese. In Europe they were first scientifically observed after the invention of the telescope, and it was deduced from their behaviour that the sun revolves about his axis in about twenty-six days. Hofrath Schwabe of Dessau, from a long series of forty years' observations of the sun, was the first to show that the state of the sun's surface as regards spots was not uniform, but that their frequency was subject to an inequality the average period of which was about eleven years. Other inequalities both of longer and shorter periods have been supposed to exist, but the eleven-yearly period is the most prominent and is best assured. Although the sun-spot catalogue of Schwabe is the first with pretensions to completeness, yet Professor Rudolf Wolf has endeavoured to render observations of sun-spots made at different times and by different observers comparable with each other, and has formed a list exhibiting approximately the relative number of sun-spots for each year. This list extends back into the 17th century, and is of great value in confirming past all doubt the existence of the eleven-yearly period. It will appear below that the sun is probably to be regarded as giving out most light and heat at those times when sun-spots are most frequent. The most accurate and now universally adopted method of estimating sun-spots is to take the spotted area expressed in millionths of the sun's visible hemisphere.

To return from this digression,—the correspondence between sun-spots and declination ranges detected by Sabine was of such a nature that years of large declination range agreed with those of many sun-spots, and *vice versa*. In the same year with Sabine (1852) Dr Rudolf Wolf and M. Gautier independently remarked the same coincidence. Subsequent discussions have entirely confirmed the fact of this connexion, and in May 1879 William Ellis (*Phil. Trans.*, 1880, p. 541) showed that the observations made at the Greenwich Observatory during the years 1841–77 indicated a relation of this nature between the diurnal ranges of horizontal force as well as those of magnetic declination on the one hand and the amount of sun-spot frequency on the other. The general character of this coincidence between sun-spot frequency and declination range is exhibited graphically in fig. 39 below.

47. *Ratios of Ranges in Years of Maximum and Years of Minimum Sun-Spot Frequency.*—Broun (*Trans. Roy. Soc. of Edin.*, vol. xxvii.) has shown that the ratios of the diurnal ranges of declination in years of maximum to those in years of minimum sun-spot frequency for places widely apart on the surface of the earth are very nearly alike. This will be seen from the following table:—

TABLE VII.—*Ratios of Declination Ranges in Years of Maximum and of Minimum Sun-Spot Frequency.*

Place	Mean Ratio $\left(\frac{\text{max}}{\text{min.}}\right)$	Observer.
Paris..........................	1·71	Cassini and Arago.
Göttingen..................	1·74	Gauss.
Munich......................	1·66	Lamont.
Dublin........................	1·52	Lloyd.
Hobart Town..............	1·57	Kay.
Toronto.......................	1·51	Younghusband and Lefroy.
Trevandrum...............	1·56	Broun.

48. *Closeness of Correspondence—Lagging behind of Ranges.*—Stewart has shown from a discussion of the declination ranges at Kew, Trevandrum, and Prague (*Proc. Roy. Soc.*, March 22, 1877, February 8, 1878, May 16, 1878) that this correspondence between the state of the sun's surface and the diurnal range of declination extends to inequalities of short period as well as to that of which the period is approximately eleven years, but that a particular state of the sun's surface precedes in point of time that of the declination range to which it corresponds,—in fine, that the solar cause precedes the terrestrial effect, which latter lags behind to an extent that is sometimes considerable. These conclusions have been confirmed by Ellis (*ut supra*), and have likewise been extended by him to the horizontal force. The close nature of this correspondence, as well as the lagging behind of the terrestrial magnetic effect, will be seen from fig. 35.

There are indications that this lagging behind of the magnetic effect is greater for sun-spot inequalities of long than for those of short period, a method of behaviour quite similar to what we find in meteorological phenomena.

49. *Analysis of Long-Period Inequalities.*—We possess no sun-spot

data sufficiently accurate for a discussion, in a complete manner, of questions relating to solar periodicity before the time when Schwabe had finally matured his system of solar observations, which was not until the year 1832. We have, however, a much longer series of the diurnal ranges of magnetic declination, which we have seen to

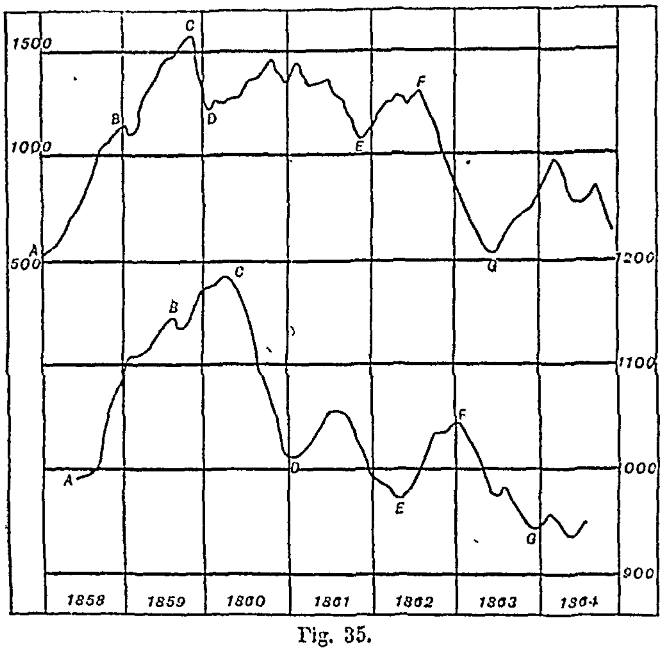

Fig. 35.

follow very closely all the variations of sun-spot frequency, so it is conceivable that they may give us a better estimate of true solar activity than that which can be derived from the direct measurement of spotted areas.

These considerations have induced Messrs Stewart and Dodgson to attempt an analysis of the diurnal ranges of magnetic declination, their method being that which has been pursued by Baxendell and probably other astronomers with observations of variable stars.[1] The observations at their disposal for this research were those which had been used by Professor Elias Loomis in his comparison of the mean daily range of the magnetic declination with the extent of the black spots on the sun (*American Journal of Science and Arts*, vol. I. No. cxlix.). These observations are recorded as monthly means of diurnal declination range, and it was found necessary to multiply each by a certain factor, first on account of the change of declination range from one month to another, and secondly to bring them all to the standard of the Prague observations,—Prague being the place where the longest series of such observations has been made. For this latter purpose precisely the same corrections were applied as those made by Professor Loomis.

The result of this analysis has been to indicate the existence of three inequalities,—two dominant ones with periods of about ten and a half and twelve years, and a subsidiary one with a period of about sixteen and a quarter years. By these means the observed annual values of declination range have been reproduced with an average error of 39″. The amount of agreement between the observed and calculated values will be seen from the following diagram (fig. 36).

50. Notwithstanding the considerable amount of agreement

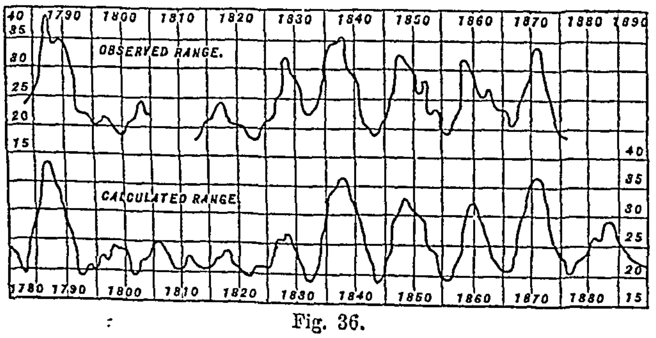

Fig. 36.

between the results of observation and calculation which appears in the diagram, it would seem that the series of observed values at present obtainable is too short to render the analysis a very accurate one. It will certainly not bear carrying back forty or fifty years beyond its starting point, which was in 1784, and it would be very hazardous to carry it forward any considerable length into the future. It will be seen that calculation indicates a maximum of declination range about 1884, but not so pronounced a maximum as that of 1871. Here then we have a prevision which observation will either fulfil or contradict, giving us a practical test of the value of this analysis.

51. The remarks now made would seem at first sight to imply that we are not yet furnished with sufficient yearly records either of declination ranges or of accurate sun-spot observations to enable us to analyse the long-period solar inequality with such completeness as to carry our calculations more than a very short distance into the future with any chance of success, and that we may have to wait for another hundred years' observations before we are able to do so. On reflection, however, it would seem that long-period inequalities may be caused by the superposition of those of short period, and thus that an analysis of the latter may lead to that of the former. It would relieve us if this were found to be the case; for the observations at our disposal may be sufficient to enable us completely to analyse short-period inequalities, assuming that we have in such the elements of a true periodicity.

A remark made by the authors of the above analysis would seem to indicate that a connexion of this nature between long and short periods does in all probability exist. It is a well-known fact that the so-called eleven-yearly oscillations of declination range are at certain times large and at other times small. Thus, for instance they have been large for the last forty years, but they were small about the earlier part of the present century. Now it is clear from an inspection of the observations (see fig. 36) that a series of large oscillations is accompanied with an exaltation of the base line, or line denoting average efficiency, while a series of small oscillations is accompanied with a depression of the same. The result is a long-period curve of the base line, the beat period, so to speak, of the eleven-yearly inequality.

Now a phenomenon precisely similar occurs in connexion with shorter periods. If we take inequalities having a period of three or four months, we find that such are alternately well-developed or of large range and badly-developed or of small range, and that a large range of such is accompanied with an exaltation of the base line or line of average efficiency, while a small range is accompanied with a depression of the same. The result is a curve of the base line of which the period is roughly speaking eleven years. May we not therefore imagine that the so-called eleven-yearly period, or, to speak more correctly, the ten and a half and twelve-yearly periods into which the eleven-yearly period may perhaps be analysed, may be in reality beat periods for shorter disturbances? Is it not therefore possible that a study of these shorter periods may give us information regarding the nature of the eleven-yearly period, whether for sun-spots or declination ranges, which the small series of actual observations is incompetent to afford?

52. *Declination-Range Weather.*—Allusion has already been made to magnetical weather as perhaps having laws similar in some respects to those which regulate meteorological weather. Now the diurnal ranges of magnetic declination and those of atmospheric temperature present us with elements of the two weathers that can easily be discussed. Again there is strong evidence for supposing that an element of meteorological weather, such, for instance, as temperature-range, travels as a rule from west to east, so that a peculiar style of temperature-range might be expected to appear first in America and some days afterwards in Great Britain. It becomes therefore a question for inquiry whether this travelling from west to east applies also to magnetical weather as evidenced by the diurnal declination-range. Stewart is of opinion that this law of travelling applies to both, but that magnetical weather travels faster than meteorological (see *Proc. Roy. Soc.*, January 10, October 23, 1879, and June 9, 1881). From the preliminary discussion made by him it would appear that Kew lags behind Toronto as regards phase of magnetical weather by 1·6 days, that Prague lags behind Kew 0·7 days, and that Trevandrum lags behind Kew by 9·7 days. This conclusion cannot, however, be regarded as established until it is confirmed by a more complete discussion of observations.

53. *Disturbance-Diurnal Variation of Declination.*—Magnetic storms (§ 38) were so named by Baron Humboldt, one of the first observers of such phenomena. From observations at Paris, Berlin, and Freiburg he found that very frequently, though not universally, these three stations were simultaneously affected by such storms. The observation of magnetic disturbances was afterwards pursued in a systematic manner by Gauss and Weber of Göttingen. Term days were instituted for this purpose by these observers,—that is to say, periods each of twenty-four hours length during which observations were simultaneously made at intervals of five minutes at Göttingen and about twenty other stations distributed generally over the continent of Europe. Finally, the establishment by the British Government of the colonial magnetic observatories, and the energy and sagacity of their director, Sir E. Sabine, have very greatly increased our knowledge of these remarkable phenomena.

Sabine has not merely separated the disturbed from the undisturbed observations as explained in § 38, but he has divided the former into two categories—(1) those tending to increase westerly

[1] *Proc. Lit. and Phil. Society of Manchester*, March 8, 1881.

declination and either element of force, and (2) those tending to diminish the same. He finds that these two categories obey different laws, from which he argues that there are at least two sets of disturbing forces. In fact, if we have to give up the idea of a single force of constant type, it is natural to ask if the phenomena of disturbance can be approximately represented as due to the united action of two independent types of force. It was probably some such idea that led Sabine to separate disturbances into these two categories above mentioned. Here there is no attempt to assert that these two types represent an ultimate and complete analysis of the forces concerned. We merely use the separation as the most convenient method at our disposal in the present state of our knowledge for ascertaining whether there be indications of a dual system.

54. *Results in the Northern Hemisphere.*—Sabine's method of viewing the phenomena has enabled him to obtain the disturbance-diurnal variation for the following stations:-

Kew	51° 29′ N. lat.	0° 8′ W. long.
Peking	39 54 N. „	116 6 E. „
Nertchinsk	51 19 N. „	114 9 E. „
Toronto	43 40 N. „	79 0 W. „
Port Kennedy	72 01 N. „	94 20 W. „
Point Barrow	71 21 N. „	156 15 W. „

The above stations have been so chosen that Kew may be regarded as on one side and Peking and Nertchinsk as probably on the other side of the Asiatic pole, while Toronto may be regarded as on one side and Port Kennedy and Point Barrow as on the other side of the American pole (§ 29). The question as to what influence, if any, these poles have upon the disturbance-diurnal variation of declination is thus one which may be answered by examining the results obtained at these various stations. For this purpose, instead of recording the aggregate disturbances at the various hours, the result is expressed in ratios,—the mean hourly ratio for the day being taken as unity, or in other words the whole body of disturbances for the twenty-four hours being reckoned as twenty-four. The results of this method are graphically represented in fig. 37, where in the left-hand curves Kew time is used, and in the right-hand curves local time, each starting at 0h.[1]

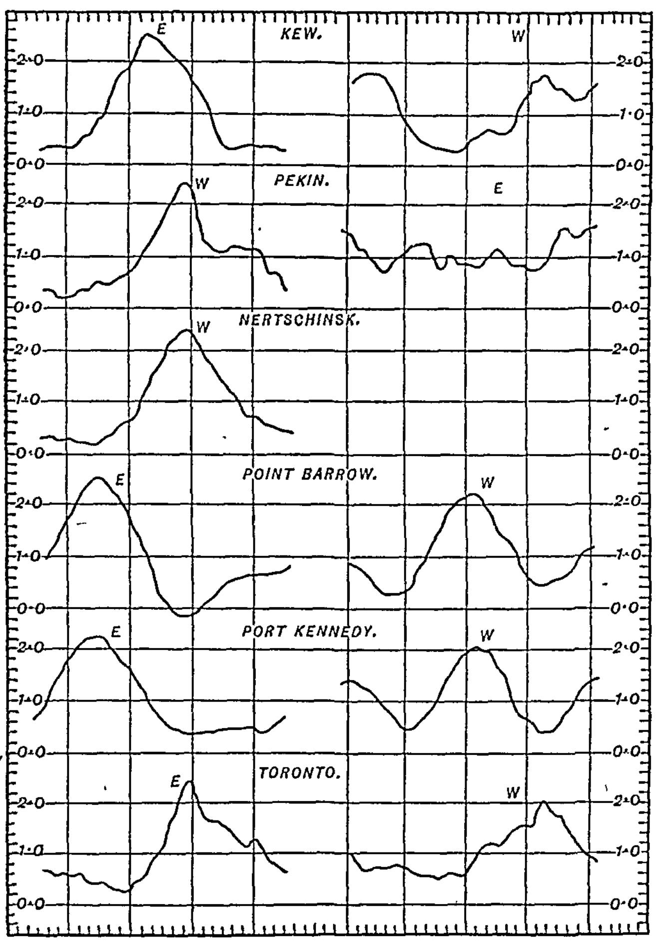

Fig. 37.

55. At all the various stations one curve exhibits unmistakably a single progression, while the other exhibits more or less distinctly a double progression. At Kew, Toronto, Port Kennedy, and Point Barrow it is the easterly disturbances which exhibit this single progression; while, on the other hand, at Peking and Nertchinsk, stations which are oppositely related to the Asiatic magnetic centre, it is the westerly disturbances which do so. It is imagined by Sabine and others that this peculiar reversal is due to the fact that Kew and its associated stations may be regarded as on one side and Peking and Nertchinsk as on the other side of the movable magnetic system.

Sabine has likewise remarked that the single-progression curves, whether denoting easterly or westerly disturbances, exhibit maxima which take place not far from the same absolute time. We have therefore plotted all the left-hand curves according to Kew time, that the eye may readily see the amount of simultaneity which their corresponding phases exhibit. It will be noticed that there is a very striking simultaneity between the maxima of Kew, Toronto, Peking, and Nertchinsk, but that the maxima for Port Kennedy and Point Barrow, while both occurring about the same time, fall at a time decidedly if not very greatly different from that of the other maxima. Indeed the time of maximum for Port Kennedy and Point Barrow is not far from the time of minimum for the other stations. Now it has been noticed by Sabine that Port Kennedy and Point Barrow may be regarded as on one side of the American magnetic centre of intensity, while Toronto and the other associated stations are on the other side. It seems therefore possible to connect this last fact with the change in the time of maximum. Sabine has likewise remarked that the aggregate amount of disturbances is much greater at Point Barrow than at any other station. Now Point Barrow is likewise that spot where auroras are most frequent. Thus in the phenomena we are now discussing there is first of all a marked reference to the Asiatic pole; secondly, a reference not so marked, perhaps, to the American pole; and thirdly, a reference to the centre of auroral activity. Sabine, whose experience of such matters is very great, appears to think most of the reference of these phenomena to the Asiatic pole. He thinks that "of the two magnetic systems which are distinctly recognizable in the magnetism of the globe one has a terrestrial and the other a cosmical source," and that it is "the latter of these two systems which, by its progressive translation, gives rise to the phenomena of secular change and to those magnetic cycles which owe their origin to the operation of the secular change," concurring with the conclusion of Walker that "the magnetic influence at any point of the globe is the result of two distinct magnetic systems, the principal of which is the magnetism proper of the globe, having its (northern) point of greatest attraction in the north of the American continent, whilst the weaker system is that which results from the magnetism induced in the earth by cosmical action, and of which the northern point of greatest attraction is at present in the north of the Asiatic continent. Thus the direction of the magnet at any point results from the superposition of these two systems, the nearest pole being always predominant over the more remote" (*Phil. Trans.*, 1868). While disposed to think that something of this nature should be accepted as a working hypothesis, we would, however, point out that the Asiatic pole cannot be regarded as accounting for all the phenomena of disturbances, but that the focus of disturbance is probably nearer the focus of auroras than it is to either of the foci of magnetic intensity.

The right-hand curves representing these disturbance-diurnal variations which have two maxima are, except for Port Kennedy and Point Barrow, decidedly irregular. Sabine remarks also that, instead of having a reference to absolute time like those with one progression, their reference is rather to local time. We have therefore plotted all these curves according to local time; nevertheless this reference does not come out with very great distinctness; but it must be remembered that our analysis of disturbances into easterly and westerly, although, in the hands of Sabine, it has given us much new information, has no claim to be regarded as final and complete.

56. *Results in the Southern Hemisphere.*—Table VIII. shows the disturbance-diurnal variation of declination exhibited for St Helena, 15° 56′·7 S. lat., 5° 40′·5 W. long.; Cape of Good Hope, 33° 56′ S. lat., 18° 28′·75 W. long.; Hobart Town, 42° 52′·5 S. lat., 147° 27′·5 E. long.

At St Helena and the Cape the easterly disturbances present the appearance of a single progression, while the same remark slightly modified applies to the easterly disturbances at Hobart Town. Again the times of easterly maxima for St Helena and the Cape are very nearly simultaneous, while Hobart Town, which we may regard as situated on the opposite side of the chief southern magnetic centre from St Helena and the Cape, has its maximum nearly coincident in absolute time with the minimum of the other two stations. It would thus seem that the chief magnetic centre of the south is similar in its action as regards these phenomena to the chief magnetic centre of the north. Again the absolute time of single maximum for the south as determined by St Helena and the Cape is about twelve hours different from the corresponding time for the north as determined by Kew, Toronto, Peking, and Nertchinsk. All this is in favour of the working hypothesis already mentioned.

[1] If we refer to a paper by C. Chambers, director of Bombay Observatory (*Phil. Trans.*, 1868), it will be seen that westerly disturbances at Bombay present the same characteristics as westerly at Peking or Nertchinsk, the maximum being about twenty-two or twenty-three hours Bombay astronomical time.

TABLE VIII.

Local Astronomical Hours.	St Helena.		Cape of Good Hope.		Hobart Town.	
	Easterly Ratios.	Westerly Ratios.	Easterly Ratios.	Westerly Ratios.	Easterly Ratios.	Westerly Ratios.
0	3·24	2·46	2·1	1·6	1·14	0·65
1	3·17	2·39	2·1	1·2	1·26	0·64
2	2·79	1·88	1·6	1·0	1·32	0·71
3	2·00	1·44	1·0	0·8	1·40	0·56
4	0·89	1·29	0·8	0·7	1·39	0·56
5	0·34	0·76	0·4	0·6	1·32	0·52
6	0·14	0·45	0·4	0·8	1·16	0·72
7	0·05	0·50	0·1	1·2	0·62	1·04
8	0·03	0·44	0·1	1·2	0·40	1·31
9	0·03	0·37	0·2	1·2	0·32	1·79
10	0·07	0·43	0·1	1·1	0·28	1·96
11	0·00	0·42	0·2	0·8	0·74	2·31
12	0·00	0·31	0·3	0·7	0·62	2·05
13	0·00	0·32	0·4	0·6	0·55	1·72
14	0·01	0·24	0·2	0·6	0·63	1·52
15	0·00	0·29	0·4	0·5	0·85	1·26
16	0·00	0·28	0·4	0·4	1·07	0·84
17	0·08	0·24	0·5	0·4	0·87	0·47
18	0·39	0·42	1·0	0·8	1·02	0·44
19	0·87	0·89	1·8	1·2	1·53	0·53
20	1·52	1·52	2·3	1·4	1·58	0·70
21	2·51	1·72	2·3	1·7	1·41	0·55
22	3·08	2·21	2·5	1·8	1·27	0·55
23	2·78	2·60	2·7	1·7	1·24	0·62

Finally, the westerly disturbances at the three southern stations bear greater marks of a double progression and of irregularity just as they did in the northern hemisphere, and moreover like their northern analogues they are regulated by local rather than by absolute time.

57. *Distribution of Declination Disturbance over the Various Months of the Year.*—Broun was probably the first to remark in reducing the Makerstoun observations that the disturbances were greatest at the equinoxes and least at the solstices. His method was to find for each month the mean diurnal inequality, and then to consider the difference of each individual observation from the monthly mean for that hour as a disturbance, the summation of all such differences for the month denoting the monthly disturbance value. The following table embodies the results at various stations—those at Toronto, Hobart Town, and the Cape being given by Sabine, and that at Bombay by C. Chambers, who has pursued Sabine's method of separating disturbances:—

TABLE IX.—*Monthly Distribution of Declination Disturbances.*

	Toronto.		Bombay.		Cape of Good Hope.		Hobart Town.	
	Easterly.	Westerly.	Easterly.	Westerly.	Easterly.	Westerly.	Easterly.	Westerly.
January	0·55	0·57	0·84	0·88	2·1	1·4	1·62	1·54
February	0·81	0·85	0·89	0·67	1·7	1·3	1·16	1·05
March	0·97	0·89	1·29	0·93	0·7	1·1	1·11	1·11
April	1·23	1·24	1·04	1·29	1·3	1·6	1·26	1·18
May	0·94	0·93	0·57	1·00	0·3	0·9	0·65	0·51
June	0·83	0·55	0·73	0·82	0·3	0·4	0·30	0·32
July	1·35	1·13	1·18	1·83	0·6	0·6	0·51	0·54
August	1·37	1·17	1·64	1·29	0·4	0·4	0·84	0·73
September	1·63	1·66	1·20	1·04	0·8	0·9	1·29	1·50
October	1·12	1·17	1·52	1·31	1·2	1·0	1·22	1·27
November	0·70	0·88	0·40	0·41	1·2	1·0	0·73	0·95
December	0·50	0·98	0·68	0·53	1·2	1·2	1·29	1·29

58. A careful inspection of this table, without attempting a more complete analysis, will, it is thought, lead to the following conclusions:—

(1) Although for any station the distribution of the easterly disturbances over the various hours of the day is generally different from that of the westerly, yet the same law of distribution over the various months of the year is followed by the easterly and by the westerly disturbances at any station—the law at one station being, however, different from that at another.

(2) In all stations there is first an annual inequality exhibiting a maximum generally a short time after the summer solstice with a corresponding minimum for the winter solstice, and secondly a semi-annual inequality exhibiting a maximum generally a little after each equinox.

(3) The equinox maximum is very conspicuous at Toronto; but the summer maximum is most conspicuous at the other stations.

59. In § 38 it was observed that the observations selected as disturbed at any station may nevertheless be a mixture of what may be termed true disturbances and of the more prominent specimens of magnetic weather. The truth of this statement would appear to be borne out by the laws now given. In one of these we find that disturbances, at all stations, have a maximum about the time of the summer solstice and a corresponding minimum about the time of the winter solstice. But the absolute time of the summer solstice for stations north of the equator corresponds with that of the winter solstice for stations south of the line. It would therefore appear that in so far as this law is concerned such disturbances lack the element of simultaneity. On the other hand, a law of this nature would naturally hold for magnetic weather. For at any station the diurnal range of declination is greatest at the summer solstice, and hence any considerable proportional variation of this would, if represented by a fixed scale, present the appearance of being greatest likewise at this time. The question thus arises whether this law does not rather apply to magnetic weather than to real disturbance.

Again the semiannual inequality of disturbance exhibits throughout the globe a maximum at the equinoxes, and thus presents the element of simultaneity which was wanting in the annual. This law may therefore refer to true disturbance, and this view is supported by the fact that the aurora—which may be regarded as the universal accompaniment of great and simultaneous disturbances—obeys, as we shall afterwards see, in those stations where it has been well observed, this very same law, that is to say, it has likewise maxima at the equinoxes.

60. *Distribution of Declination Disturbances over Various Years.*—In 1852 Sabine discovered (*Phil. Trans.*, 1852, p. 103) that disturbances have a long-period inequality allied to that of sun-spots in such a way that a maximum and a minimum of disturbance coincide with a maximum and a minimum of sun-spot frequency.

This will be seen from the following table (X.), in which we have the relative values of declination disturbance at Toronto and Hobart Town compared with the number of groups of spots observed on the sun's disk:—

	Values of Declination Disturbance.		Groups of Sun-Spots.
	Toronto.	Hobart Town.	
1843	0·55	0·48	34
1844	0·73	0·82	52
1845	0·62	0·67	114
1846	1·26	1·03	157
1847	1·40	1·44	257
1848	1·43	1·60	330

61. The following table (XI.) exhibits the same thing for Bombay. The first column of this table is derived from the magnetic results of C. Chambers, while the sun-spot areas are those of Messrs De la Rue, Stewart, and Loewy.

	Aggregate Values (in Minutes) of Declination Disturbances.	Sun-Spot Areas.
1859	1532·1	1352
1860	1421·6	1313
1861	951·8	1297
1862	1240·5	1211
1863	691·1	676

We may conclude from these tables that declination disturbances march with sun-spots, but that the alliance between these two phenomena is probably not so intimate as that between declination ranges and sun-spots.

62. *Distribution of Declination Disturbances over the Surface of the Globe.*—It is well known that disturbances are comparatively small near the equator, while they are great near the magnetic poles, and greatest of all perhaps near the position of maximum auroras. If we adopt Sabine's system of separating disturbed from undisturbed observations, it is thus clear that the same separating value cannot be adopted at all stations. At first sight this would seem to introduce an element of uncertainty in the estimation of disturbances, but it was soon found by Sabine that no very great nicety is required in this matter. Not only do the laws which regulate disturbances at a given station remain comparatively unaffected by the magnitude of the separating value, but it is likewise easy to tell whether the aggregate disturbance value at one station is decidedly greater or less than at another. Probably at present it would be impossible to obtain more definite information than this.

63. The following table (XII.) exhibits the proportion between the aggregate amount of easterly and that of westerly disturbances of the declination at various stations in both hemispheres:—

Name of Station.	Easterly.		Westerly.
Toronto	1·40	:	1
Point Barrow	1·63	:	1
Port Kennedy	1·85	:	1
Carlton Fort	1·74	:	1
Kew	1·19	:	1
Peking	1	:	1·21
Bombay	1·6	:	1
St Helena	1	:	1·30
Cape of Good Hope	1	:	1·51
Hobart Town	1	:	1·40
Falkland Isles	1·66	:	1

64. *Annual Variation of Declination.*—The declination fluctua-

tions of short period hitherto discussed are not necessarily accompanied by a permanent change of mean position of the needle. We have now to inquire whether there be any fluctuations of long period (besides the secular change discussed in §§ 30-33) tending to alter perceptibly the position of the magnetic needle. This leads us at once to the annual variation, for our knowledge of which we must look to the later-made and more accurate observations, in which all possible sources of error have been carefully eliminated. Broun has made an exhaustive experimental inquiry into the various sources of error which could possibly influence his declination needle at Trevandrum. His conclusion was that the variations of torsion of a well-made thread are not sufficient to produce a sensible effect upon the position of a powerful magnet. In fact Grubb's magnet, weighing 6000 grains, and Adie's, weighing 1100 grains, give almost identical results. We may extend these conclusions to other observatories where well-devised instruments have been established, and look with much confidence to such instruments registering correctly the secular as well as the annual change of declination that may be taking place at each locality.

65. The following table (XIII.), borrowed, with the exception of the Trevandrum and Bombay results, from E. Walker's *Terrestrial Magnetism*, shows the annual variation at seven stations:—

	Mean Declination.	Mean Annual Secular Change.	Observation Years.
	° ′	″	
Kew	21 39 W.	7 39·00 E.	1858–62
Hobart Town	9 56 E.	1 23·20 W.	1844–48
St Helena	23 27 W.	7 57·00 W.	1841–49
The Cape	29 7 W.	0 29·40 W.	1841–46
Toronto	1 35 W.	1 57·12 W.	1845–51
Trevandrum	0 35 E.	1 35·4 E.	1854–69
Bombay	0 31 E.	3 1·0 E.	1859–65

TABLE XIV.—*Showing the Mean Annual Variation for each Month of the Year at Seven Stations.*

	Kew.	Toronto.	St Helena.	Cape of Good Hope.	Hobart Town	Trevandrum.		Bombay.
						Grubb.	Adie.	
	″	″	″	″	″	″	″	″
April	+ 1·5	− 0·6	− 2·4	+64·2	−22·2	+ 1·2	+ 6·3	+11·0
May	−41·8	− 9·6	− 1·2	−10·8	−28·7	+ 3·4	+ 8·7	+16·3
June	−50·6	−17·4	−13·8	−62·4	−24·1	+ 5·6	+ 8·7	+ 9·8
July	−70·3	−42·6	+ 8·4	−58·2	−20·6	+ 1·6	+ 2·2	+ 1·7
August	−20·7	− 4·2	− 3·6	−61·8	−12·2	− 2·8	− 3·2	+ 1·6
September	+ 9·8	+47·4	−19·8	−43·2	− 4·5	− 8·7	−10·5	+ 0·4
October	+49·6	+61·0	+ 1·8	− 4·8	+13·6	− 8·0	−11·1	− 8·9
November	+34·8	+24·6	+ 7·2	+25·2	+27·6	+ 1·2	− 3·0	+ 1·2
December	+39·6	+19·8	+ 7·2	+42·6	+38·5	+ 3·3	− 1·3	−18·2
January	+ 2·6	+ 4·2	− 3·0	+29·4	+32·9	+ 7·1	+ 3·2	−10·9
February	+34·2	+ 0·6	+18·0	+43·2	+ 7·9	+ 2·3	+ 2·6	+ 3·1
March	+29·8	− 7·8	+10·2	+49·8	+16·7	− 4·9	− 1·2	− 7·0

Here + indicates that the marked pole of the needle is to the west and − that it is to the east of its mean position for the year.

66. To cancel the irregularities of this table let us take the means from April to September and from October to March, the former embracing the months around the June solstice and the latter those around the December solstice (Table XV.):—

	Means from April to September.	Means from October to March.
	″	″
Kew	−28·7	+31·8
Toronto	− 4·5	+17·1
St Helena	− 5·4	+ 6·9
Cape of Good Hope	−28·7	+30·9
Hobart Town	−18·7	+17·3
Trevandrum	+ 2·1	− 1·6
Bombay	+ 6·8	− 6·8

It will be seen from the above that the means for Trevandrum and Bombay present opposite signs to those for the other stations. The whole amount for Trevandrum is no doubt very small, and Chambers does not regard the evidence for Bombay as conclusive; but on the whole it would appear that two observatories near one another present evidence of a similar behaviour in declination, and we are therefore disposed to regard it as a reality.

67. *Semiannual Variation of Declination.*—If we look at the numbers of Table XIV., we shall see that there are traces of turning points at the equinoxes. Let us, in order to exhibit this, compare together the sums for the six months grouped around the two equinoxes with those for the six months grouped around the two solstices—that is to say, compare the sums for February, March, April, August, September, October, with those for November, December, January, May, June, July—and we thus obtain the following table (XVI.):—

	Sums around Equinoctial Months.	Sums around Solstitial Months.
Kew	+104·2	−85·7
Toronto	+ 96·4	−21·0
St Helena	+ 4·2	+ 4·8
Cape	+ 47·4	−34·2
Hobart Town	− 0·7	+25·6
Trevandrum	− 19·0	+20·3
Bombay	+ 0·2	− 0·1

68. *Solar-Diurnal Variations of the Horizontal and Vertical Components of Magnetic Force.*—Although self-recording magnetographs have been established in many observatories throughout the globe, yet, owing to the peculiar difficulties of the task, and the labour of the process of reduction, very little has been done towards determining the solar-diurnal variation of the horizontal and vertical components of the earth's magnetic force. Senhor Capello of the Lisbon Observatory has, however, made progress with his reductions, and has already published valuable information regarding the solar-diurnal fluctuation of the two force elements at his observatory.

In his attempts to eliminate the disturbances of horizontal and vertical force by the method of Sir E. Sabine, Senhor Capello has experienced considerable difficulty, more particularly with the records of the vertical force magnetograph. This instrument and the bifilar have very often been found by him to change their position of equilibrium after strong perturbations. Again there is generally, for any hour, a variation at the beginning and end of the month from the monthly normal value for that hour owing to change of temperature, and this cannot be completely corrected inasmuch as the coefficient of temperature is not exactly known. These two causes combined tend to falsify the results when the plan adopted is the method of comparison between the individual values of any hour and the normal monthly average of that hour. Senhor Capello has found it necessary to select and extract the disturbances, not directly from the hourly values, but by comparing the variation of an individual day with the average diurnal variation derived from the month.

To illustrate this method by means of an example, let us imagine that the sum of the twenty-four hourly values for a particular day is 24,000, and that the average monthly diurnal variation would indicate that a particular hour of this day should have a value 990, then, if the value for this hour should prove to be greater or less than 990 by more than a certain amount, it would be set aside as a disturbed observation. Senhor Capello rather thinks it will be desirable somewhat to modify this method, and he concludes his remarks by observing that for this and other similar questions it is most necessary that directors of establishments possessing magnetographs should agree together to employ the same method in their reductions in order that their results may be comparable with each other. With the view of adding weight to these remarks, we may quote the observation of Sir William Thomson, that our ability to analyse mathematically that influence which produces the diurnal variation will depend upon our knowing at a certain number of stations the exact nature of this diurnal variation for each of the three magnetic elements. A complete theory of this diurnal influence must therefore wait upon the concerted action of the directors of the various establishments possessing magnetographs.

69. *Change in Horizontal Force Range from Month to Month.*—Although we do not possess finally accurate determinations of the solar-diurnal variations of either element of the force, yet we are in possession of information regarding the change in the diurnal range of the horizontal force from month to month at the Greenwich Observatory. William Ellis has given us the following table (*Phil. Trans.*, 1880) representing the monthly mean diurnal range of horizontal force at that observatory expressed in ten-thousandths of the whole horizontal force. In the formation of these means, days of great magnetic disturbance were rejected, and also certain other days on which there prevailed a smaller but considerable amount of disturbance estimated according to a general standard formed in the examination of many thousands of photographs.

TABLE XVII.—*Monthly Mean Diurnal Range of Horizontal Force at Royal Observatory, Greenwich.*

Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
13·5	14·8	20·1	27·4	26·9	27·3	27·2	25·2	23·2	19·8	14·3	11·6

Thus, like the declination range (§ 43), the horizontal force range has a maximum in summer and a minimum in winter, and exhibits a tendency towards maxima at the equinoxes.

70. *Long-Period Inequalities of Horizontal Force Range.—Lagging Behind.*[1]—Ellis has compared the diurnal range of the horizontal force as well as that of the declination at Greenwich with the period of sun-spot frequency, his comparisons extending from 1841 to 1877, and he has deduced the following conclusions:—

[1] Secchi (*Wolf's Astronomische Mittheilungen*, No. 21) seems to have been the first to indicate a relation between the state of the sun's surface and the diurnal variation in the horizontal force.

(1) The diurnal ranges of the magnetic elements of declination and horizontal force are subject to a periodical variation, the duration of which is equal to that of the known eleven-year sun-spot period.

(2) The epochs of minimum and maximum of magnetic and sun-spot effect are nearly coincident, the magnetic epochs on the whole occurring somewhat later than the corresponding sun-spot epochs. The variations of duration in different periods appear to be similar for both phenomena.

(3) The occasional more sudden outbursts of magnetic and sun-spot energy, extending sometimes over periods of several months, appear to occur nearly simultaneously, and progress collaterally.

71. *Disturbance-Diurnal Variation of Force Components.*—We may derive the following conclusions from the results obtained by Sabine for the observatories of Toronto, Kew, and St Helena. For each element there are two categories, namely, those disturbances which tend to increase and those which tend to diminish the element in question.

(1) At Toronto the disturbances increasing both elements of force well represent single progressions with maxima occurring for both about 4 or 5 hours local time. Again the disturbances decreasing both elements represent fairly well single progressions with maxima occurring for both at about 14 or 15 hours local time.

(2) At Kew the disturbances increasing both elements represent well single progressions with maxima occurring for both about 5 hours local time. On the other hand, the disturbances decreasing the horizontal force represent signs of a double progression and those decreasing the vertical force signs of a single progression, the maximum for the latter falling between the two maxima for the former, and occurring at 14 hours local time.

(3) There is not the same close correspondence between the progress of the disturbances which tend to increase both elements nor between the progress of those which tend to decrease both elements at St Helena as there is for the other stations, nor is there the same likeness between the numbers for St Helena and those of Toronto or Kew as there is between the numbers of Toronto and those of Kew.

72. The fact that the disturbance-diurnal variations of the two force elements at Kew are very like each other while neither of them is very like the corresponding declination variation (§ 54) receives confirmation from a visual inspection of the Kew curves. In the *Philosophical Transactions* for 1862 Stewart thus describes the result of an inspection of the disturbances of these curves for the years 1858, 1859, 1860 (disturbance years):—

"There are twenty-two cases in which the declination is raised or lowered along with the horizontal force, and only seven cases of an opposite description. Also there are twenty-two cases in which the declination is raised or lowered along with the vertical force, and only eleven cases of an opposite description. Finally, there are thirty-one cases in which both forces are raised or lowered together, and only two cases of an opposite description. There is therefore a decided tendency in the curves of all the elements to be raised or lowered simultaneously, but this tendency is stronger between the horizontal and vertical force curves than between either of these and the declination. It may at the same time be affirmed that with the exception of the disturbance of August to September 1859 there is no very prominent case in which the three elements do not rise or fall together."

73. *Peaks and Hollows.*—These are certain small but abrupt magnetic changes which from the fact that they generally fall within the separating value are not usually regarded as disturbances. These changes can only be brought to light where there is a continuous record of magnetic phenomena such as that derived from self-recording magnetographs. They were first studied at the Kew Observatory by Stewart (*Phil. Trans.*, 1862). We have seen that more than one type of force must be concerned in producing magnetic disturbances. This is confirmed by the appearance of the Kew records, from which it may be seen that no disturbance of any magnitude is due to the action of a single force varying merely in amount but not in direction. For if there were only one type of force the distance at any moment of a point in the curve of one of the elements from its normal position should bear throughout a disturbance an invariable proportion to the distance of a corresponding point in the curve of another of the elements from its normal; but this is by no means the case.

But even if several independent forces are at work it may be thought unlikely that at the same moment a sudden change should take place in all; there is thus a probability that sudden changes of force, as exhibited in peaks and hollows, are changes in one of the elementary forces concerned. Even if the change is not a very abrupt one, provided that we confine ourselves to such peaks and hollows as present a similar appearance for all the curves, we may suppose that we are observing changes in one only of the elementary disturbing forces; for it is unlikely that two or more independent forces, changing independently, should produce similar appearances in all of the three curves.

Assuming it as probable that similarity of appearance in the curve variations of the three elements denotes a simplicity in the disturbing force, Stewart has discussed all such peaks and hollows at Kew extending over the first two years of their production, and has obtained a result which is embodied in the following table:—

TABLE XVIII.—*Hourly Ratios and Frequency of the Kew Peaks and Hollows, the Vertical Force Disturbance being taken as Unity.*[1]

Hour.	Declination.	Hor. Force.	Number of Observations.	Hour.	Declination.	Hor. Force.	Number of Observations.
0– 1	2·14	2·06	7	12–13	1·76	2·68	3
1– 2	1·97	2·16	7	13–14	2·00	2·04	3
2– 3	1·86	1·99	11	14–15	2·10	2·14	5
3– 4	1·81	2·05	7	15–16	2·65	2·11	10
4– 5	1·38	1·73	4	16–17	3·48	2·16	15
5– 6	1·57	1·71	1	17–18	3·80	2·14	22
6– 7			0	18–19	3·94	2·18	28
7– 8	1·82	1·91	2	19–20	3·97	2·25	21
8– 9	1·60	2·20	1	20–21	3·41	2·21	23
9–10			0	21–22	3·26	2·30	16
10–11	1·33	3·16	1	22–23	2·79	2·00	10
11–12	1·30	2·32	3	23–24	2·30	2·04	13

74. It will be seen from this table that the ratio between simultaneous peaks and hollows of the two components of the force is very nearly constant, the horizontal force disturbance being about double that of the vertical force, so far as size on the curve is concerned. It will also be seen that there is a very marked diurnal range in the ratio which the declination peak or hollow bears to that of the vertical force, this ratio being greatest about 7 A.M. About this hour we have also most peaks and hollows, while in the evening and early morning hours there is so great an absence of these phenomena that the ratios are doubtful.

75. A preliminary comparison between the peaks and hollows at Lisbon and at Kew has been made by Capello and Stewart (*Proc. Roy. Soc.*, January 28, 1864) with the following conclusions.

(1) The Kew peaks and hollows are simultaneously produced at Lisbon in all the elements, but to a smaller extent than at Kew.

(2) The direction is the same at both stations for the declination and horizontal force peaks and hollows, but it is reversed in the case of the vertical force, so that a sudden small increase of vertical force at Kew corresponds to a diminution of the same at Lisbon.

It would be manifestly impossible to discuss with any advantage the nature and origin of these peculiar changes until more extensive observations of them have been made. As the peak and hollow force is probably of a simple nature, a further knowledge of its character may be of much importance to the theory of terrestrial magnetism.

It is interesting to remark that we have in peaks and hollows the same close relation between the variations of the two force elements that we find in the larger disturbances.

It is believed too that during violent disturbances a certain change of type is produced in the peak and hollow force, and more especially is this remarkable in the great disturbance in August and September 1859, where the declination would seem to march in the opposite direction from the two components of the force. We have seen that the same peculiarity characterized on this occasion the larger and more apparent magnetic changes. We shall afterwards refer to a circumstance which may perhaps throw light upon this peculiarity (§ 93), meanwhile we conclude by again remarking that during comparative magnetic calms the peak and hollow force shows signs of remaining constant in type, and that it is therefore of great importance that the directors of observatories possessing self-recording magnetographs should take united action to observe this force.

76. *Other Inequalities of the Disturbance-Diurnal Variation of the Force Components.*—Sabine has shown that disturbances of the force components present a distribution over the various months of the year very similar on the whole to that which is exhibited by disturbances of declination. He has likewise shown that disturbances of the force components present a distribution over various years similar to that exhibited by disturbances of declination. Finally, we may probably conclude that disturbances of the force components are smallest at those portions of the earth's surface where disturbances of the declination are smallest, and largest at those portions where such disturbances are largest.

77. *Annual and Semiannual Variation of Horizontal Force and Dip.*—Broun (*Trans. Roy. Soc. Edin.* for 1861) has discussed the results obtained by Sabine at his magnetical stations, and has shown that differential and absolute observations agree in telling us that the horizontal force is smallest at the equinoxes and greatest at the solstices. Whipple has recently obtained the same result from the Kew observations.

We have deduced the following table (XIX.) from the various absolute determinations that have been made at sundry places. In it the annual and semiannual variations of declination, horizontal force, and dip are exhibited, "increase" denoting a push to the west, and "decrease" a push to the east. The method of obtaining these has already been indicated in §§ 66, 67.

[1] We ought to mention that, with the exception of the one occasion already alluded to, a peak of one element always corresponds to a peak of another element, and a hollow of one element to a hollow of another.

Station.	Effect on Declination.		Effect on Horizontal Force.		Effect on Dip.	
	At Equinoxes compared to Solstices.	At June Solstice compared to December Solstice.	At Equinoxes compared to Solstices.	At June Solstice compared to December Solstice.	At Equinoxes compared to Solstices.	At June Solstice compared to December Solstice.
Makerstoun or Kew	Increase.	Decrease.	Decrease.	Inappreciable.	Increase.	Decrease.
Toronto	Increase.	Decrease.	Decrease.	Increase.	Inappreciable.	Decrease.
Cape of Good Hope	Increase.	Decrease.	Decrease.	Increase.		
Hobart Town	Decrease.	Decrease.	Decrease.	Decrease.	Decrease.	Decrease.
Trevandrum	Decrease.	Increase.				
Bombay	Undecided.	Increase.				
St Helena	Undecided.	Decrease.				

78. In discussing the results of this table we shall assume that the sun acts, and in all probability acts indirectly, upon the magnetic system of the earth. This point will afterwards be further examined. Meanwhile, assuming this indirect action of the sun, and assuming, to fix our thoughts, that it is in close alliance with the convection system of the earth's atmosphere, we can readily imagine that such solar action would act most strongly on the earth's magnetic poles at the solstices, and that in the June solstice the pole or poles in the northern hemisphere and in the December solstice those in the southern hemisphere would be most affected. Now a strong action of this kind upon either magnetic pole may well be presumed to increase the general magnetism of the earth, or at least that portion of it which is most readily affected by external action, that is to say, the induction system. Again, if the solar magnetic influence is connected with the convection currents of the earth, we can readily imagine that the influence in the northern hemisphere where there is much land should exceed that in the southern hemisphere where there is much water.

If these views be reasonable we might expect two things to follow:—(1) the earth's induction system should be stronger at the solstices than at the equinoxes, and (2) it should be more especially strong at the June solstice, when the sun acts in the northern hemisphere. We must bear in mind, however, that so vast is the earth that a stimulus applied to its particles most susceptible of magnetism may not be instantaneously propagated throughout its mass, but that time may enter as an element of the question, in which case, inasmuch as the action of the sun at the June solstice is in the northern hemisphere, a station near the south pole may not fully partake of the magnetic effects of this action.

79. An hypothesis of this nature would appear to be consistent with the results of Table XIX.

In the first place, if the earth should become stronger as a magnet in one or in both of its magnetic systems this would show itself by an increase of horizontal force at least in all such stations as those at which absolute observations are made. An influence which increases the horizontal force at these various stations is therefore naturally regarded, and was regarded by Broun, as one increasing the strength of one or both of the magnetic systems of the earth—whether of one or of both will presently appear. We may therefore assume from our observations that one or both of the earth's magnetic systems are strongest at the solstices.

In the next place we may imagine that the changes of declination and dip which the table exhibits as occurring at the solstices are the very changes which would be wrought in these elements by an increase of power in the earth. For we see very well that an increase of horizontal force at the various stations may be regarded as denoting an increase of the earth's magnetic power. We cannot, however, see with equal facility what changes would be produced in the declination and dip by an increase in power of one or both of the magnetic systems; but we may well imagine that such changes of these elements as are found to accompany an increase of horizontal force are those that denote an increase of the earth's power.

We have thus ascertained the probable nature of those changes of the three elements which denote an increase of power. Now it will be noticed from the table that the effect at the June as compared with that at the December solstice is of the opposite nature to the effect at the equinoxes as compared with the solstices,—that is to say, the earth is more powerfully affected in June than in December, the only well-established exception to this being Hobart Town in the far south. But, assuming that time is an element in the development of this preponderating influence acting in the north, it is easy to see why Hobart Town should not exhibit its full effect.

It remains to determine from the observations themselves which of the magnetic systems it is that exhibits these oscillations. Analogy would of course point to the induction system, but it is desirable to determine this from the observations themselves.

In § 54, when discussing the disturbance-diurnal variation of declination, it was found that Toronto and Kew may be regarded as on one side of the Siberian pole, while Peking, Nertchinsk, and Bombay are on the other. Now, if it be this pole that is influenced by the oscillations under discussion, we might expect that the influence on declination at Toronto and Kew should be the opposite of that at Trevandrum and Bombay. We find by the table that this is the case, and we are thus inclined to attribute these changes to the Siberian instead of the American pole. It would thus appear that the observations of Table XIX. bear out the provisional working hypothesis which we have ventured to introduce. It is quite possible that these remarks may not stand the test of more complete inquiry, but they are here introduced rather as denoting a method of looking at the subject which ought we think to be pursued than as embodying conclusions of a final nature.

80. *Effect of the State of the Sun's Surface upon the Absolute Magnetism of the Earth.*—We have now to consider whether the state of the sun's surface permanently influences the magnetism of the earth. It will at once be seen that any such action will apparently manifest itself as an oscillation in the secular change. We must, however, carefully guard ourselves against prematurely concluding that it implies a variation in the amount of true secular change. There may be two distinct things—true secular change due to one cause, and action depending on sun-spots due to another. These, from the nature of the case, are necessarily mixed up together in the yearly changes which we examine; it does not, however, follow that there is any real identity between them. We shall now give one example of the method to be pursued in the attempt to detect a solar influence of this nature. Let us turn to Table III., and take the declination yearly values at Toronto from 1856 to 1871. Subtracting the value for 1856 from that for 1871, we find that the westerly declination had increased in fifteen years 51′·6, that is to say, at the mean rate of 3′·44 per annum. Again, the average declination for the sixteen years 1856–71 is 2° 20′·8 corresponding to the epoch at the commencement of the year 1864. Taking the average value and epoch, and also the average yearly increase above given, we are able to construct the following table (XX.), in which calculated and observed values at Toronto are compared together:—

	Observed.	Calculated.	Difference.
	° ′	° ′	′
1856	1 56·30	1 55·00	+1·30
1857	2 0·50	1 58·44	+2·06
1858	2 4·50	2 1·88	+2·62
1859	2 7·40	2 5·32	+2·08
1860	2 10·60	2 8·76	+1·84
1861	2 14·40	2 12·20	+2·20
1862	2 15·70	2 15·64	+0·06
1863	2 19·10	2 19·08	+0·02
1864	2 21·90	2 22·52	−0·62
1865	2 24·80	2 25·96	−1·16
1866	2 27·60	2 29·40	−1·80
1867	2 29·80	2 32·84	−3·04
1868	2 33·20	2 36·28	−3·08
1869	2 37·10	2 39·72	−2·62
1870	2 41·90	2 43·16	−1·26
1871	2 47·90	2 46·60	+1·30

It may be gathered from this table that the years which correspond to minimum sun-spots have in the last column a greater negative or lower positive sign than those which correspond to maximum sun-spots, and hence we may conclude that at Toronto the tendency of many sun-spots is to increase the westerly declination.

81. Performing a similar operation for all those cases in which we have a sufficiently extensive series of observations to work upon, we obtain the following table:—

TABLE XXI.—*Effect of Numerous Sun-Spots on the Values of Magnetic Elements.*

Station.	Declination.	Horizontal Force	Dip.
Kew	Increase.	Inappreciable.	Increase.
Toronto	Increase.	Increase.	Increase.
Hobart Town	Increase (?).	Uncertain.	Increase.
Cape of Good Hope	Decrease.		
Trevandrum	Increase.		

82. We have good grounds for supposing that the sun is most powerful when there are numerous spots on his surface, and therefore the above table represents a state of things which we may imagine to be caused in one way or another by increased solar power. Now the most natural hypothesis is to imagine that an increase of spots acts in producing an increase of disturbances, and that for those stations at which the disturbances tend on the whole to affect the elements in a definite direction there will be left behind a permanent effect in this direction. A comparison of Table XXI. with Table XII. will, however, show that this explanation is not valid. For instance, at Toronto and Kew disturbances tend rather to diminish

than to increase the westerly declination, while the effect of numerous sun-spots is to increase it. Again, at the Cape the tendency of disturbances is to increase the westerly declination, while that of numerous sun-spots is to decrease it. At Trevandrum again (if we judge of it by Bombay) the effect of disturbances will be to increase the easterly declination, while that of sun-spots is to decrease it. Again, it is believed that at Kew and Toronto the supposed disturbance effect on the dip agrees in character with the sun-spot effect. On the whole, therefore, there is no definite relation between the two effects.

Now if we take Hobart Town, the Cape, and Trevandrum in the above table, we find from Table XIX. that these stations seem to indicate that the magnetic state of the earth is most powerful at times of maximum sun-spots. Kew and Toronto, however, so far as declination and dip are concerned, appear to go the other way. If, however, we suppose that during the several years of maximum sun-spots the American pole as well as the Siberian is affected, and that on such occasions of long continuance the former has more influence than the latter, we shall be able to reconcile our results with the hypothesis of increased solar action. We can understand too that time must be an important element in any influence communicated to the American pole, and that, although such influence might be apparent at Toronto and Kew, which are comparatively near the pole, it would not be apparent at the other stations of Table XXI. We shall recur to this subject when discussing secular change.

VARIOUS PHENOMENA CONNECTED WITH THE SUN AND WITH TERRESTRIAL MAGNETISM.

83. *Closeness in Time between Solar Changes and Magnetic Disturbances.*—Loomis (*American Journal of Science*, vol. l.) has registered the extent of sun-spots for the six days preceding and following each of the great magnetic disturbances at Greenwich, and has compared these values with that for the very day of the disturbance. In this manner he has treated all the days of great magnetic disturbance at Greenwich for a period of twenty-three years, with the exception of those cases in which very few observations of sun-spots were made. The cases of disturbance thus treated amount to one hundred and thirty-five, and the following result has been obtained:—

TABLE XXII.—*Extent of Spotted Solar Surface.*

	Days before Storm.						Storm.	Days after Storm.					
	6	5	4	3	2	1		1	2	3	4	5	6
Mean of 135 Days.	47·9	50·1	54·8	53·5	52·3	48·9	57·9	49·0	45·1	49·3	45·6	45·2	45·3

From this result Loomis draws the following conclusions:—(1) great disturbances of the earth's magnetism are accompanied by unusual disturbances of the sun's surface on the very day of the magnetic storm; (2) the great disturbance of the sun's surface which accompanies a terrestrial magnetic storm is generally heralded by a smaller disturbance three or four days previous, succeeded by a comparative calm which immediately precedes the magnetic storm.

84. There is one instance on record of a sudden solar change which was practically simultaneous with a magnetic disturbance.[1] On September 1, 1859, a little before noon, R. C. Carrington was observing by means of a telescope a large sun-spot, when, to quote his own words—

"Within the area of the great north group (the size of which had previously excited general remark) two patches of intensely bright and white light broke out. . . . I noted down the time by the chronometer, and, seeing the outburst to be very rapidly on the increase, and being somewhat flurried by the surprise, I hastily ran to call some one to witness the exhibition with me, and on returning within sixty seconds was mortified to find that it was already much changed and enfeebled. Very shortly afterwards the last trace was gone; and, although I maintained a strict watch for nearly an hour, no recurrence took place. . . . The instant of the first outburst was not fifteen seconds different from 11^h 18^m Greenwich mean time, and 11^h 23^m was taken for the time of disappearance. In this lapse of five minutes, the two patches of light traversed a space of about 35,000 miles. . . . It was impossible, on first witnessing an appearance so similar to a sudden conflagration, not to expect a considerable result in the way of alteration of the details of the group in which it occurred; and I was certainly surprised, on referring to the sketch which I had carefully and satisfactorily finished before the occurrence, at finding myself unable to recognize any change whatever as having taken place. The impression left upon me is that the phenomenon took place at an elevation considerably above the general surface of the sun, and accordingly altogether above and over the great group in which it was seen projected.

"It has been very gratifying to me to learn that Mr Hodgson chanced to be observing the sun at his house at Holloway on the same day, and to hear that he was a witness of what he also considered a very remarkable phenomenon."

At the very moment when Carrington observed this phenomenon the three magnetic elements at Kew were simultaneously disturbed. This disturbance occurred as nearly as possible at 11^h 15^m A.M., affecting all the elements simultaneously, and commencing quite abruptly. The first or most abrupt portion of the disturbance lasted only about three minutes for all the elements; but after that there was a more gradual change in the same direction before the curve turned. This more gradual continuation of the first sudden movement lasted about seven minutes for all the elements. This magnetic disturbance was, however, in reality a small one, and was followed by a very great disturbance which took place not many hours afterwards.

85. *Simultaneity of Changes of Horizontal Force at Various Parts of the Earth.*—We have already (§ 79) alluded to the superiority of the horizontal force in indicating by its changes what is taking place in the magnetic system of the earth. If this system be strengthened as a whole we shall no doubt find the horizontal force increased in value at our various stations, while if the earth's power be weakened as a whole we shall find the horizontal force diminished.

Broun has discussed this subject at great length in a memoir already mentioned, and has embodied his observations in numerical results from which the following table has been extracted:—

TABLE XXIII.—*Daily Means of Horizontal Force at Makerstoun,* (M.), *Trevandrum* (T.), *Singapore* (S.), *and Hobart Town* (H.).

1844.	M.	T.	S.	H.	1844.	M.	T.	S.	H.
March 1	21·40	07·42	16·40	16·46	March 17	21·30	11·54	19·74	19·12
,, 3	18·34	05·25	14·18	13·98	,, 18	20·11	07·62	17·65	17·08
,, 4	16·53	06·42	14·59	14·49	,, 19	21·73	08·55	16·26	13·59
,, 5	11·43	04·43	12·79	10·04	,, 20	22·00	07·83	17·24	16·20
,, 6	13·94	01·85	10·42	9·66	,, 21	23·15	09·06	18·35	17·06
,, 7	12·99	04·12	12·37	9·98	,, 22	22·47	08·14	18·35	19·12
,, 8	16·94	03·81	13·62	11·50	,, 24	22·30	09·58	18·76	18·99
,, 10	19·12	04·33	14·87	14·07	,, 25	23·71	10·09	18·76	19·25
,, 11	17·64	05·87	14·87	13·97	,, 26	25·22	09·48	20·29	20·10
,, 12	18·05	06·28	15·01	14·22	,, 27	22·24	10·81	18·63	19·33
,, 13	23·25	09·58	17·65	16·18	,, 28	22·16	07·52	17·79	16·73
,, 14	23·66	10·61	18·90	17·81	,, 29	–5·97	03·50	11·54	7·82
,, 15	22·12	10·09	18·63	16·85	,, 31	17·06	02·27	11·81	10·27

This table shows a considerable likeness between the daily changes of the horizontal force at the four stations. For instance, we have a minimum which occurs on March 5 at Makerstoun and March 6 at the other stations; we have likewise a well-defined maximum occurring at all stations on March 14, and another occurring at Trevandrum on March 25, and at the other stations on March 26. Finally we have a well-defined minimum occurring at Trevandrum on March 31, and at the other stations a day earlier.

Broun has extended a similar treatment to daily means for every hour, and fig. 38 conveys a good idea of the amount of simultaneity which obtains in the changes of such values of horizontal force at stations far apart.

86. *Recurrence of Disturbances at Intervals of about Twenty-six Days.*—Broun[2] and likewise Hornstein[3] have observed that there is a tendency in large magnetic changes to recur at intervals of about twenty-six days. At first it was natural to suppose that we have here a magnetical indication of the true time of the sun's synodical rotation, the interval between two disturbances denoting that which elapses between two presentations to the earth of a peculiarly powerful solar meridian. It seems unlikely, however, that there is a really permanent one-sidedness of this kind in our luminary; but the result of observation seems to show that for a limited period, say two or three years, certain meridians of the sun appear to be peculiarly powerful. The cause of this we shall not here discuss, but simply treat the phenomenon as a fact derived from observation. Broun in his paper above quoted (*Phil. Trans.*, 1876) makes the following remarks:—

"We have seen that when one side of the sun is presented to the earth the magnetic force of the latter is greater than when the other side is turned towards us; we may even say that the intensity is greatest for a given solar meridian; this, however, may be simply an integral effect resulting from the actions due to all the meridians. But can we suppose when a great and sudden increase or diminution of the earth's magnetic force occurs that this is produced by some change occurring on a particular solar meridian? This does not seem at all improbable.

"In order to examine the facts, all the cases were noted during the years 1844 and 1845 in which the daily mean horizontal force diminished one-thousandth of its whole value within an interval of three days; they were found to be twenty-eight in number. If we call the solar meridian presented to us on the 1st January 1844 the zero meridian (0), and consider the time of rotation to be twenty-six days, and that there are twenty-six meridians, we find that the solar meridians presented to us when these great movements occurred may be arranged in a few groups, as in the following table" [Table XXIV., p. 177].

"An examination," continues Broun, "of this table will show that nearly half of the great changes began when the eighth meridian after the zero had passed, while five began near the twelfth after, and five near the zero itself. . . . If any doubt existed as to the possibility of these being mere accidental coincidences, it would be removed, I think, by a consideration of the marked succession occurring between July 31 (No. 18) and December 11, 1845 (No. 28). . . . If we neglect the two cases of July 31 and August 26, which commence at +6 and +5 respectively, we have five cases of successive solar rotations in which the diminutions of intensity began on the +8 day. This exact recurrence at the end of twenty-six days of a marked diminution of force proves, it seems to me, that the actions are all due to the sun, whose time of rotation must be nearly twenty-six days.

"An examination will show that the sudden diminutions of terrestrial magnetic force are in nearly every case preceded by a sudden increase."

In the above extract we have given the author's exact words, but, while thinking with him that these actions are due to the sun, it does not appear to us to follow that the time of the sun's rotation

[1] *Phil. Trans.*, November 21, 1861.

[2] *Phil. Mag.*, August 1858; *Phil. Trans.*, 1876.
[3] *Vienna Acad. S.*, June 15, 1871.

must be nearly twenty-six days. This assumes that the meridian of peculiar power is fixed on the solar surface. It does not, however, seem impossible to imagine that such a meridian may have a proper motion of its own, and indeed the planetary hypothesis of the origin of sun-spots would rather lead to this conclusion. But if this be the case we shall be unable to deduce from recurrent magnetic disturbances the true value of the period of solar rotation.

87. *Repetitions of Magnetic Changes.*—J. B. Capello, director of the Lisbon observatory (*Proc. Roy. Soc.*, October 1868), has remarked that at periods of disturbance there are nearly synchronous movements of the declination needle during corresponding hours for two, three, or more days. He thus describes these phenomena:—

"In some cases the repetition is only in two or three parallel movements; in others there are true periods of repetition of some hours in duration. The repeated periods are not entirely similar, their phases being so modified that in some cases their identity can only be recognized by a very minute investigation. The same periods, when repeated, have not always the same total duration; nor do they recommence at the same precise hour, but sometimes earlier and sometimes later, the differences varying from a few minutes to two or three hours. We also see that the greatest number of repetitions belong to the night hours, that is to say, those hours when the movements of the needle are easterly. In the morning hours there do not appear to be any well-marked repetitions. There are twenty-four examples now given, fifteen of which show repetition on two days, eight on three days, and only one where the curve appears repeated for four days. It appears that all the facts exhibited in these examples agree with the cosmical theory; the cause (existing in the sun or in space) appears to continue sometimes during two, three, or several days without undergoing remarkable transformations. The repetition, being sometimes earlier sometimes later, seems also to indicate that the cause possesses a proper movement; the cause persists, but only comes again into operation when the earth by its diurnal rotation is placed in a similar position or conjunction to that of the preceding days."

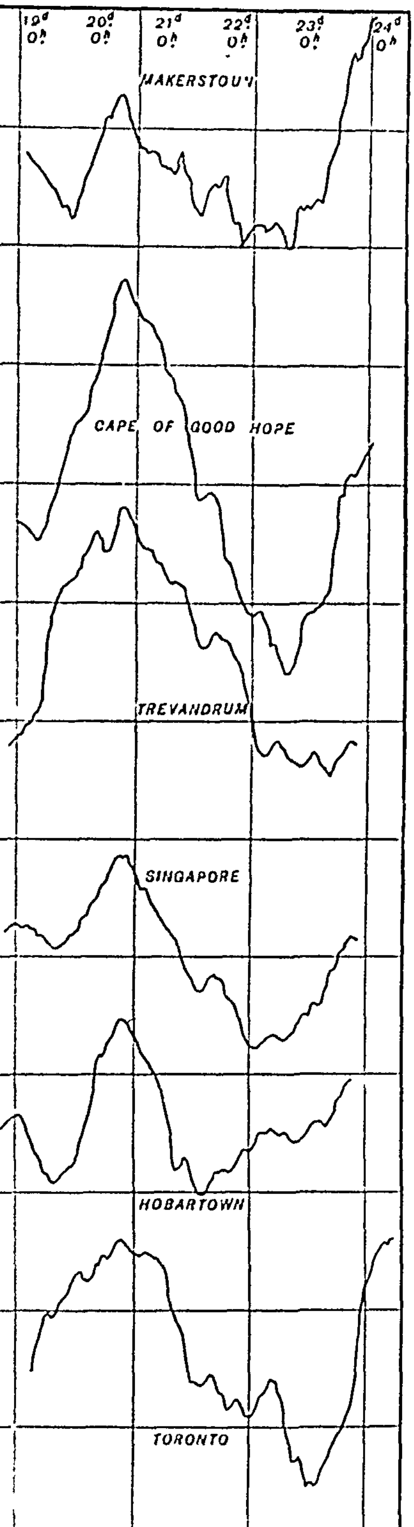

Fig. 38.

Stewart, having compared Capello's curves with the corresponding traces of the declination at Kew, found that the Lisbon disturbances are almost invariably reproduced at Kew at the same time, only to a greater extent, and also that the same amount of similarity which the various Lisbon curves exhibit is exhibited in the corresponding Kew curves. The strongest point in favour of the hypothesis is, he thinks, "not so much the repetition of a single disturbance as the repetition of a complicated disturbance in most if not all of its sinuosities." Several examples of this occur in the diagrams. It would seem that something of the above nature was suspected by Humboldt, the earliest investigator of disturbances. Humboldt was astonished to discover the frequency with which nocturnal perturbations occurred, sometimes recurring at the same hour on several successive

TABLE XXIV.—*Cases in which the Earth's Magnetic Force diminished One-thousandth of its Value or more in* 1844-45 (§ 86).

No. of Case.	Date (Jan. 1, 1844=0).	Change of Force in Hundred-thousandths.	Solar Meridians.		
			5 to 10.	11 to 14.	−3 to +1 and others.
1	87 to 89	−360	+8 to +10		
2	110 to 116	−104		+11 to +12	
3	141 to 143	−107		+11 to +12	
4	189 to 190	−116	+7 to + 8		
5	213 to 214	−175	+5 to + 6		
6	221 to 222	−135		+13 to +14	
7	267 to 270	−115	+7 to +10		
8	273 to 274	−104		+13 to +14	
9	292 to 294	−268	+6 to + 8		
10	323 to 325	−130		+13 to +14	
11	361 to 364	−165			−3 to 0
12	373 to 375	−210	+9 to +11		
13	383 to 385	−163			(−6 to −4)
14	416 to 417	−118			0 to +1
15	467 to 469	−350			−1 to +1
16	526 to 528	−110	+6 to + 8		
17	570 to 571	−154			−2 to −1
18	577 to 580	−102	+6 to + 9		
19	603 to 604	−101	+5 to + 6		
20	606 to 607	−159	+8 to + 9		
21	632 to 633	−153	+8 to + 9		
22	646 to 648	−126			(−4 to −2)
23	658 to 659	−118	+8 to + 9		
24	668 to 670	−100			(−8 to −6)
25	684 to 687	−100	+8 to +10		
26	696 to 698	−110			(−6 to −4)
27	702 to 703	−291			−0 to +1
28	710 to 712	−122	+8 to +10		

nights (Walker's *Magnetism*, p. 80). We would make two suggestions before dismissing this subject.

(1) If we imagine that these changes are caused by the solar influence acting vertically on some susceptible region of the earth, then, inasmuch as they occur at the evening or early night hours, this region must lie considerably to the west.

(2) The region must also have a proper motion of its own (see Capello's remark). Is it possible that this proper motion is on the whole from west to east,—a motion which we know is pursued by meteorological weather, and in which it is imagined (§ 52) that magnetical weather as defined by us likewise participates?

88. *Comparison of Declination Changes at Stations near each other.*—Messrs Sidgreaves and Stewart (*Pro. Roy. Soc.*, October 1868) have compared together certain curves of the Kew and Stonyhurst declination magnetographs. These magnetographs are of the same pattern, and it was found that on ordinary occasions the declination traces at both stations were precisely alike. This was confirmed by placing the curves the one over the other, when they were found to coincide even in their most minute features. In times of disturbance, however, it was found that the motions exhibited by the Stonyhurst curves were greater than those at Kew, and this excess of Stonyhurst over Kew depended not so much on the absolute size of the disturbance as on its abruptness.

This feature of the comparison is exhibited in the following table (XXV.), in which the excess of Stonyhurst over Kew in scale divisions is compared with the abruptness of the disturbance, this element being measured by the changes occurring in unit of time:—

Group I.		Group II.		Group III.		Group IV.	
Excess (under 5).	Abruptness.	Excess (under 10).	Abruptness.	Excess (under 20).	Abruptness.	Excess (above 20).	Abruptness.
2	3·7	6	4·2	10	·5	21	7·3
2	6·4	6	2 6	10	0	25	2·9
-3	4 0	8	6 3	11	7	25	10·7
0	3·1	5	3·3	10	0	20	7·0
0	3·1	8	8 7	10	·8	21	6·6
4	2 9	5	3·5	15	6·4	21	11·2
1	1·8	7	6·3	11	4·9	22	9·6
4	3·3	9	4·7	13	7·4	24	7·8
3	5·2	5	4·1				
Means 1·5	3 7	6 6	4·9	11	6·5	22	7·9

It is very desirable that further comparisons of this nature should be made.

89. *Auroral Displays.*—These are very frequent if not continuous near the magnetic poles, while in middle latitudes they are the invariable accompaniments of all considerable magnetic storms. Near the equator they hardly ever occur.

There is a considerable variety in the forms assumed by these displays, and it is possible that this may denote a corresponding variety in the cause or causes which give rise to this phenomenon.

Loomis (*Smithsonian Report* for 1865) specifies five such varieties: (1) a horizontal light like the morning aurora or break of day; (2) an arch of light which frequently extends entirely across the heavens from east to west and cuts the magnetic meridian

nearly at right angles,—in the polar regions five such arches have been seen at once; (3) slender luminous beams or columns well-defined and often of a bright light; (4) the corona, the centre of which is invariably near the magnetic zenith, but not always exactly coincident with it; and (5) waves or flashes of light.

90. Auroras exhibit the same annual variation as magnetic disturbances, and are most frequent about the equinoxes—a fact first observed by Maizan. Kaemtz in his *Meteorology* gives the following table, which is applicable to European auroras.

TABLE XXVI.—*Monthly Frequency of European Auroras.*

Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
229	307	440	312	184	65	87	217	405	497	285	225

Loomis again in the memoir already quoted gives the distribution of American auroras over the various months derived from one hundred and thirteen years' observations at New Haven and Boston, twenty-five years' observations at New York, and two years' observations in Canada. His results are represented in the following table:—

TABLE XXVII.—*Monthly Frequency of American Auroras.*

	Boston and New Haven.	New York.	Canada.	Sum.
January	81	76	16	173
February	93	86	31	210
March	110	106	24	240
April	104	125	38	267
May	86	83	22	191
June	83	79	17	179
July	123	100	21	244
August	102	122	14	238
September	143	131	19	293
October	99	110	27	236
November	115	74	26	215
December	83	60	16	159

It appears from this table that American like European auroras exhibit a maximum of frequency about the equinoxes.

91. Since auroras and magnetic disturbances go together, it is natural to imagine that we should have great auroral displays in years of maximum sun-spots. This is found to be the case, and in the following table (XXVIII.) Wolf's proportional numbers denoting sun-spot frequency are compared with the number of auroras witnessed in Europe and America as compiled by Loomis. It will be seen from this table that years of maximum auroras coincide very well with years of maximum sun-spots.

	Sun-Spot Number.	Auroral Number.		Sun-Spot Number.	Auroral Number.		Sun-Spot Number.	Auroral Number.
1750	83·1	31	1794	38·0	14	1837	136·9	42
1751	52·1	30	1795	23·8	7	1838	104·1	60
1752	45·9	17	1796	15·6	8	1839	83·4	65
1753	28·9	15	1797	6·5	5	1840	61·8	80
1754	13·5	11	1798	4·6	6	1841	38·5	67
1755	9·3	10	1799	7·1	4	1842	23·0	53
1756	12·2	9	1800	15·6	6	1843	13·1	37
1757	31·9	7	1801	33·9	6	1844	19·3	39
1758	47·1	14	1802	54·7	6	1845	38·3	48
1759	54·6	16	1803	70·7	6	1846	59·6	54
1760	64·7	23	1804	71·4	14	1847	97·4	76
1761	80·2	22	1805	48·0	14	1848	124·9	72
1762	60·0	19	1806	28·4	13	1849	95·4	69
1763	48·4	16	1807	11·1	4	1850	69·8	49
1764	36·7	11	1808	7·2	2	1851	63·2	65
1765	21·4	8	1809	3·1	1	1852	52·7	67
1766	14·1	5	1810	0·0	1	1853	38·5	63
1767	35·9	9	1811	1·6	0	1854	21·0	35
1768	66·8	30	1812	4·9	1	1855	7·7	20
1769	103·4	40	1813	12·6	4	1856	5·1	11
1770	98·5	41	1814	16·2	5	1857	22·9	21
1771	86·6	24	1815	35·2	5	1858	56·2	37
1772	65·7	26	1816	46·9	5	1859	90·3	50
1773	39·7	33	1817	39·9	7	1860	94·8	48
1774	27·4	33	1818	29·7	11	1861	77·7	36
1775	8·8	22	1819	23·5	10	1862	61·0	28
1776	21·7	24	1820	16·2	8	1863	45·4	29
1777	92·0	38	1821	6·1	4	1864	45·2	33
1778	151·7	69	1822	3·9	2	1865	31·4	34
1779	123·4	70	1823	2·6	1	1866	14·7	31
1780	89·2	67	1824	8·1	1	1867	8·8	22
1781	66·5	57	1825	16·2	4	1868	36·8	32
1782	38·7	57	1826	35·0	12	1869	78·6	
1783	22·5	47	1827	51·2	17	1870	131·8	
1784	10·3	39	1828	62·1	21	1871	113·8	
1785	26·7	56	1829	67·2	25	1872	99·7	
1786	81·2	84	1830	67·0	25	1873	67·7	
1787	128·2	108	1831	50·4	20	1874	43·1	
1788	134·3	105	1832	26·3	13	1875	18·9	
1789	116·9	84	1833	9·4	11	1876	11·7	
1790	90·6	68	1834	13·3	12	1877	11·1	
1791	67·6	46	1835	59·0	15	1878	3·8	
1792	59·9	37	1836	119·3	32	1879	7·7	
1793	47·3	23						

In fig. 39 a graphical representation is given of the likeness which subsists between the progress of auroral frequency, spot frequency, and declination ranges.

92. While the results now given leave little doubt as to the fact of a connexion of some sort subsisting between sun-spots on the one hand and magnetic disturbances and auroras on the other, yet it is desirable to obtain evidence as to the closeness of the connexion between auroras and sun-spots similar to that which was exhibited in § 82, and which showed the close connexion in point of time between sun-spots and disturbances. Loomis has with this view treated auroras in precisely the same way in which he treated disturbances, and has obtained the following table:—

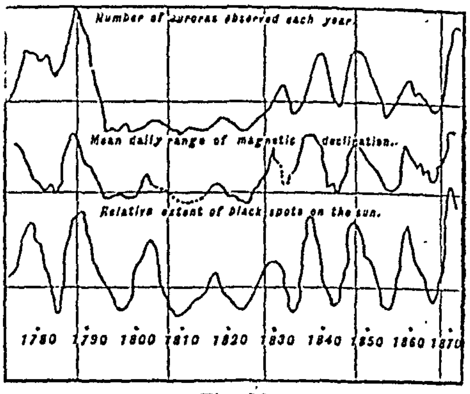

Fig. 39.

TABLE XXIX.—*Extent of Spotted Solar Surface.*

	Days before Aurora.						Aurora.	Days after Aurora.					
	6	5	4	3	2	1		1	2	3	4	5	6
Mean of 251 Days.	50·3	52·7	51·0	51·2	53·1	53·7	60·5	51·8	52·5	53·3	51·4	53·3	50·7

From which he concludes that "auroral observations in the middle latitudes of America are generally accompanied by a maximum disturbance of the sun's surface on the very day of the aurora."

93. *Earth Currents.*—These are electrical currents which take place in the moist crust of the earth, and were first detected by W. H. Barlow (*Phil. Trans.*, 1849). At a later period they were systematically observed and studied by C. V. Walker (*Phil. Trans.*, 1862). They are now continuously recorded by photography at the Royal Observatory, Greenwich. Earth currents are particularly strong during magnetic disturbances. Sir George Airy has graphically compared together certain magnetic disturbances as recorded by the Greenwich self-recording magnetographs and the simultaneous earth currents recorded by appropriate galvanometers (*Phil. Trans.*, 1868), and finds it almost impossible to avoid the conclusion that the magnetic disturbances are produced by terrestrial *galvanic currents below the magnets.* The likeness between the two systems of graphical representations is unquestionably very striking. But, while there is no doubt an intimate connexion between earth currents and magnetic disturbances, there is one circumstance which should make us pause before assigning the former as the complete and efficient cause of the latter. It is thus indicated by Lloyd:[1]—

"When we examine the curves in which Mr Barlow has represented the course of the galvanometric deflexions caused by the earth currents, we observe that the regularity of that course is continually interrupted by rapid reciprocating movements in which the needle oscillates from one side to the other of the zero alternately. These movements are similar to those of the magnetometers with which we are familiar; *but they are much more rapid*, and bear a larger proportion to the regular changes. . . . I have selected for calculation the observations made during the six hours commencing at 3 A.M. on May 29, 1848, that being a period of comparative disturbance. The sum of the changes of the galvanometer needle during that period, on the Derby and Rugby line, was *equivalent to 571 divisions of the instrument—the mean daily range* for the entire week being 11·4 divisions and the ratio=50. . . . The sum of the changes of the Greenwich declinometer during the same period was only 57 minutes, the mean daily range being 12·4 minutes. In like manner the sum of the changes of the horizontal force was ·0158 and the mean daily range ·0034. *The ratio is accordingly the same for the two magnetic elements*, and its amount is 4·6, or less than one-tenth of the corresponding ratio in the case of the galvanometrical changes. We learn therefore that the rapid changes of the earth currents are much greater in proportion to the regular daily changes than the corresponding movements of the magnetometers."

We shall return to this subject in a subsequent part of this article.

94. *Inequalities in Terrestrial Magnetism caused by the Moon.*—Kreil in 1841 was the first to point out that the moon has a small influence on the position of the declination needle, and shortly afterwards the same fact was independently discovered by John Allan Broun. The more recent observations of Sabine and of Broun, but especially those of the latter, have thrown much light upon the nature of this action. As the lunar influence is not generally large, it is necessary to free the observations from the results of other inequalities, and this has beendone by the two observers above mentioned. The results given in Table XXX. have been obtained by Sabine (see Walker's *Magnetism*).

95. Thus (1) the mean effect of the moon upon the declination needle is to cause in each lunar day a double oscillation, and Sabine has shown that the lunar influence upon the other magnetic elements is of a similar type. (2) The turning points for both hemispheres are in all cases not far removed from the lunar hours

[1] *Trans. Roy. Irish Acad.*, xxiv. 115.

TABLE XXX.—*Mean Lunar-Diurnal Variation in Declination.*

Lunar Hour.	Kew.	Toronto.	Peking.	St Helena.	Cape.	Hobart Town.
	"	"	"	"	"	"
0	− 6·2	−18·9	−4·2	+2·6	+ 8·9	+5·9
1	− 9·6	−16·5	−3·3	+0·3	+ 6·4	+8·3
2	− 8·4	− 9·5	−1·5	−2·2	+ 2·1	+8·5
3	− 2·0	− 0·1	+0·7	−4·2	− 2·6	+6·4
4	− 0·6	+ 9·2	+2·6	−5·1	− 6·5	+2·7
5	+ 4·0	+15·9	+3·7	−4·6	− 8·4	−1·6
6	+ 9·0	+18·1	+3·9	−2·9	− 7·9	−5·3
7	+11·3	+15·3	+3·0	−0·3	− 4·9	−7·3
8	+ 9·6	+ 8·2	+1·3	+2·6	− 0·3	−7·2
9	+ 4·7	− 0·4	−0·6	+4·9	+ 4·7	−4·9
10	− 0·1	−10·7	−2·2	+6·1	+ 8·6	−1·0
11	− 5·5	−17·3	−3·1	+5·9	+10·6	+3·4
12	− 9·6	−19·4	−2 9	+4·4	+ 9·9	+7·2
13	−11·3	−16·3	−1·7	+1·9	+ 6·7	+9·1
14	− 9·5	− 8·9	+0·2	−0·8	+ 1·8	+8·8
15	− 5·4	+ 1·0	+2·3	−3·1	− 3·5	+6·3
16	− 0·6	+10·8	+4·0	−4·4	− 7·9	+2·1
17	+ 5·1	+17·8	+5·0	−4·4	−10·3	−2·7
18	+ 8·5	+20·2	+4·8	−3·1	−10·1	−6·7
19	+ 9·8	+17·4	+3·5	−1·0	− 7·3	−9·1
20	+ 8·8	+10·2	+1·5	+1·5	− 2·7	−9·1
21	+ 7·4	+ 0·4	−0·8	+3·5	+ 2·4	−6·8
22	+ 2·4	− 9·3	−2·9	+4·4	+ 6·7	−2·8
23	− 1·6	−15·9	−4·1	+4·1	+ 9·2	+1·8

In this table + indicates that the north end of the magnet is to the east and − that it is to the west of its mean position.

0, 6, 12, 18. (3) In the northern stations we have a maximum westerly deflexion about the hours 0 and 12 and a maximum easterly deflexion about the hours 6 and 18, while in the southern stations the action is the reverse of this. (4) The oscillations would appear to be most decided at those stations, such as Toronto and Hobart Town, that are far removed from the equator.

96. *Annual Variation of Lunar Effect.*—Broun has recently studied with much success the peculiarities of the lunar influence at Trevandrum, and has obtained some very unexpected results. His first result was that the nature of the lunar influence upon the declination needle at Trevandrum depends upon the time of the year, and that the southern type of lunar action predominates at Trevandrum during the winter and the northern type during the summer months. If we take the mean of the whole year, then probably the southern type will be found to predominate.

97. *Mean Lunar-Diurnal Variation during the Day and during the Night.*—Broun has shown that the action of the moon on the declination needle at Trevandrum is greater in every month of the year during the day than during the night. The following table (XXXI.) gives the day and night ranges for the various months and their ratios:—

Range.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	′	′	′	′	′		′	′	′	′	′	′
Day	0·85	0·47	0·49	0·41	0·24	0·36	0·40	0·39	0·31	0·23	0·41	0·69
Night...	0·24	0·26	0·23	0·22	0·14	0·11	0·22	0·18	0·21	0·21	0·20	0·23
Ratio....	3·6	1·8	2·1	1·8	1·6	3·2	1·9	2·1	1·5	1·1	2·1	3·0

It would appear from Broun's observations that there is a difference of type as well as a difference of range.

98. *Lunar-Diurnal Variation with Reference to the Moon's Distance.*—Both Sabine and Broun have shown that this variation is greater for perigee than for apogee. Broun has found that the mean ratio of the apogee effect to the perigee effect is as 1 to 1·24 nearly. He remarks that "the ratio of the moon's mean distance from the earth in the half orbit about apogee is to that in the half orbit about perigee nearly as 1·07 is to 1; as the cube of 1·07 is 1·23 nearly, we see that the mean ranges of the curves for the two distances are in the approximate ratios of the inverse cubes of the moon's distance from the earth, as in the theory of the tides."

99. *Lunar-Diurnal Variation with Reference to the State of the Sun's Surface.*—Kreil in a memoir presented to the Imperial Academy of Science in 1852 considers that the observations at Prague and Milan tend to show the existence of a solar period in the lunar variations. Sabine (*Phil. Trans.*, 1856) has discussed the Toronto observations and also (*Phil. Trans.*, 1857) the Hobart Town observations with the view of deciding this important point, and has come to the conclusion that there is no systematic difference in the lunar-variation corresponding to the decennial period of the solar-diurnal variation, but merely such casual fluctuations as might be reasonably expected, considering the shortness of the periods which they represent.

We have made a preliminary discussion of Broun's Trevandrum observations with the view of throwing a little more light on this subject. For this purpose we have taken the ranges of the lunar-diurnal variations recorded by him for each month of each year. We have in the first place grouped these ranges together into threes, representing quarterly results, and have then compared together these quarterly results for years of small and for years of great sun-spot frequency,—assuming the years 1854–56 and 1863–64 to represent the former, and the years 1857–62 to represent the latter. We have thus obtained the following result:—

TABLE XXXII.—*Relation between Lunar-Diurnal-Ranges of Declination at Trevandrum and Sun-Spot Frequency.*

	Great Sun-Spot Frequency.	Small Sun-Spot Frequency.
	′	′
February, March, April..............................	0·501	0·493
May, June, July..............................	·461	·380
August, September, October..............................	·504	·419
November, December, January..............................	·641	·533

It would appear from this table that such ranges are greater at years of maximum than at years of minimum sun-spot frequency. Nevertheless the proof is not conclusive, inasmuch as associated with such lunar ranges we may have remnants of solar disturbance, the tendency of which might possibly be to increase the apparent range. Now such disturbances are more frequent at times of maximum sun-spots, and it might therefore be conjectured that this tendency would be to increase the apparent lunar range at such times above the range corresponding to years of minimum sun-spots. On the whole we are not disposed to think that the evidence already adduced is sufficient to decide this question as a matter of fact either in the one direction or in the other.

100. *Variation in the Diurnal Range of Declination depending upon the Age of the Moon.*—Capello (*Annals of Lisbon Observatory*, 1876) and Stewart (*Proc. Roy. Soc.*, 1877) have separately found that the range of declination is greatest about the times of new and full moon, a result recently confirmed by C. Chambers of Bombay. The following are the results recorded by Stewart derived from 197 lunations at the Kew Observatory:—

TABLE XXXIII.—*Variation of Diurnal Range of Declination with Moon's Age,* (0) *denoting New and* (4) *Full Moon.*

Phase of lunation........	(0)	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Value of range............	519	512	499	499	507	508	499	503

101. *Earth Currents caused by Lunar Influence.*—Mr Alexander J. S. Adams (*Nature*, March 3, 1881) has made use of a telegraph wire the ends of which were connected with the earth, the one at Cardiff and the other at London. He observed the currents on this wire every quarter of an hour from March 28 to April 26, 1879. He believes that such are earth currents, and that they have a lunar-diurnal variation. There are during the lunar day, according to this observer, four electrical maxima, two positive and two negative, each maximum being divided from the next by a zero or point of no current. His results likewise exhibit a regular retardation or lagging of the earth-current variations behind the corresponding phase of the moon to the extent of nearly three hours, but these require confirmation from further observations.

THE EFFECT OF SOLAR VARIABILITY ON THE METEOROLOGY OF THE EARTH.

102. We may learn from the preceding paragraphs that the sun exercises a more powerful influence upon the magnetism of the earth at times of maximum than at times of minimum sun-spots. It remains now to find whether a similar variability obtains in the phenomena of terrestrial meteorology. For this purpose we may divide the meteorological elements into the four divisions of pressure, rainfall, wind, and temperature, inquiring in what manner these are affected by solar inequalities.

103. *Pressure.*—In 1871 Baxendell (*Memoirs of the Lit. and Phil. Society of Manchester*, 1871–72), from an analysis of eleven years of the Radcliffe observations, Oxford, came to the conclusion that in years of maximum sun-spots the maximum barometric pressure occurred under north-east winds and the minimum under south-west, while in years of minimum sun-spots the maximum and minimum pressures took place respectively under north and south-east winds. He came likewise to the conclusion that, besides this difference in distribution of the convection currents of the earth, the forces which give rise to the movements of the atmosphere appear to be more energetic in years of maximum than in years of minimum sun-spots.

104. A study of the isobaric lines would appear to be the best method of obtaining information upon this important point. It is well known that during summer the interiors of large continents have a peculiarly low and the surrounding oceans a peculiarly high atmospheric pressure; while a disposition exactly the reverse obtains during the winter months. All this is no doubt due to solar action, and we might therefore imagine that when the sun is peculiarly powerful these peculiarities of distribution will be found to be increased in prominence, while they will be diminished at times of comparatively weak solar influence.

The distribution of pressure has been studied with much success by the Indian meteorologists, including Messrs Archibald, Blanford,

Broun, Charles and Frederick Chambers, Eliot, and Hill, and the following conclusion is the result of their labours. We may assume that the Indo-Malayan region has for the mean of the year a barometric pressure probably below the general average of the earth. We might therefore imagine that during years of powerful solar influence this peculiarity would be increased. Now these observers have found that in this Indo-Malayan region the barometer is abnormally low during times of maximum sun-spots. Again, western Siberia is a district which in the winter season has a pressure decidedly above the average, and we should therefore imagine that during years of powerful solar influence this winter pressure should be peculiarly high. But this is what Blanford has found in his discussion of the Russian stations to correspond with years of maximum sun-spots.[1]

Again, Frederick Chambers has enunciated the following laws as resulting from his discussion of various meteorological records:—

(1) Variations of the sun-spot area are succeeded some months afterwards in the Indo-Malayan region by corresponding abnormal barometric variations, a high barometer corresponding to a minimum of sun-spots.[2]

(2) This lagging behind is greater for easterly than for westerly stations. In other words, this, like other meteorological phenomena, appears to travel from west to east.

We may therefore conclude that the barometric evidence as far as it goes is in favour of the hypothesis that the sun is most powerful at times of maximum sun-spots.

105. *Rainfall—Heights of Rivers and Lakes.*—In 1872 Meldrum of the Mauritius Observatory brought forward evidence showing that the rainfalls at Mauritius, Adelaide, and Brisbane were on the whole greater in years of maximum than in years of minimum sun-spots. Shortly afterwards it was shown by Lockyer (*Nature*, December 12, 1872) that the same law was observable in the rainfalls at the Cape of Good Hope and Madras.

Meldrum has since found that the law holds for a great number of stations, including eighteen out of twenty-two European observatories, with an average of thirty years' observations for each. The results are exhibited in the following table (XXXIV.):—

Name of Observatory.	Number of Years of Observation.	Excess (+) or defect (−) in maximum Sun-Spot years.
		Inches.
1. St Petersburg	41	+15·18
2. Christiania	31	+19·65
3. Edinburgh	31	+65·85
4. Königsberg	19	−22·79
5. Berlin	11	+10·85
6. Utrecht	11	+ 0·44
7. Munster	13	+22·72
8. Greenwich	22	−11·73
9. Breslau	33	+49·90
10. Bonn	11	+ 8·90
11. Brussels	41	−13·84
12. Prague	29	+23·37
13. Paris	64	−28·76
14. Vienna	11	+ 9·24
15. Kremsmünster	41	−18·55
16. Nicolaieff	11	− 6·44
17. Geneva	41	− 6·15
18. Milan	29	−11·81
19. Rome	18	+15·30
20. Lisbon	11	+ 3·65
21. Palermo	41	+ 4·35
22. Athens	11	+10·86

It would, however, appear from the observations of Governor Rawson that the rainfall in Barbados forms an exception to this rule, being greatest about the times of minimum sun-spots.

106. Gustav Wex in 1873[3] showed that the recorded depth of water in the rivers Elbe, Rhine, Oder, Danube, and Vistula for the six sun-spot periods from 1800 to 1867 was greater at times of maximum than at times of minimum sun-spot frequency. These conclusions have since been confirmed by Professor Fritz.[4]

Quite recently Stewart (*Proc. Lit. and Phil. Soc. of Manchester*, 1882) has treated the evidence given by Fritz as regards the Elbe and Seine in the following manner. He divides each sun period, without regard to its exact length, into twelve portions, and puts together the recorded river heights corresponding in time to similar portions of consecutive sun periods. He finds by this means residual differences from the average representing the same law whether we take the whole or either half of all the recorded observations, and whether we take the Elbe or the Seine. The law is that there is a maximum of river height about the time of maximum sun-spots and another subsidiary maximum about the time of minimum sun-spots. There is some reason too to think that the Nile and Thames agree with those rivers in exhibiting a maximum about the time of maximum sun-spots and a subsidiary maximum about the time of minimum sun-spots, only their subsidiary maximum is greater than it is for the Elbe and Seine.

107. In 1874 G. M. Dawson came to the conclusion that the levels of the great American lakes were highest about times of maximum sun-spots. In this investigation the value of the evidence derived from rivers and lakes is no doubt greater than that derived from any single rainfall station, inasmuch as in the former case the rainfall of a large district is integrated and irregularities due to local influence thus greatly avoided.

108. Dr Hunter, director-general of statistics in India, has recently shown (*Nineteenth Century*, November 1877) that the recorded famines have been most frequent at Madras about the years of minimum sun-spots—years likewise associated with a diminished rainfall.

109. *Winds and Storms.*—Meldrum of the Mauritius Observatory found in 1872, as the result of about thirty years' observations, that there are more cyclones in the Indian Ocean during years of maximum than during years of minimum sun-spots.[5] The connexion between the two is exhibited in the following table:—

TABLE XXXV.—*Comparison of the Yearly Number of Cyclones occurring in the Indian Ocean with the Yearly Number of Spots on the Sun.*

Character as regards Sun-Spots.		Number of Hurricanes.	Number of Storms.	Number of Whole Gales.	Number of Strong Gales.	Total Number of Cyclones.	Number of Cyclones in Max. and Min. Periods.
	1847	5	0	0	0	5	
Max.	1848	6	2	0	0	8	23
	1849	3	2	3	2	10	
	1850	4	3	1	0	8	
	1851	4	2	1	0	7	
	1852	5	0	3	0	8	
	1853	1	1	2	1	5	
	1854	3	1	0	0	4	
Min.	1855	3	2	0	0	5	13
	1856	1	0	2	1	4	
	1857	2	1	1	0	4	
	1858	3	1	3	2	9	
	1859	3	2	6	4	15	
Max.	1860	7	4	2	0	13	39
	1861	5	2	2	2	11	
	1862	4	2	2	2	10	
	1863	5	2	1	1	9	
	1864	2	2	1	0	5	
	1865	2	2	3	0	7	
Min.	1866	1	4	2	1	8	21
	1867	0	4	2	0	6	
	1868	3	2	2	0	7	
	1869	3	1	3	2	9	
Max.	1870	2	1	5	3	11	31
	1871	3	2	3	3	11	
	1872	6	5	1	1	13	
	1873*	4	5	3	0	12	

* Up to May 31.

In 1873 M. Poëy[6] found a similar connexion between the hurricanes of the West Indies and the years of maximum sun-spots. He enumerated three hundred and fifty-seven hurricanes between 1750 and 1873, and stated that out of twelve maxima ten agreed.

110. In 1877 Mr Henry Jeula, of Lloyd's, and Dr Hunter found that the casualties on the registered vessels of the United Kingdom were $17\frac{1}{2}$ per cent. greater during the two years about maximum than during the two years about minimum in the solar cycle.

111. *Temperature.*—Baxendell, in a memoir already quoted, was the first to conclude that the distribution of temperature under different winds, like that of barometric pressure, is sensibly influenced by the changes which take place in solar activity. In 1870 Piazzi Smyth published the results of an important series of observations made from 1837 to 1869 with thermometers sunk in the rock at the Royal Observatory, Edinburgh. He concluded from these that a heat wave occurs about every eleven years, its maximum being not far from the minimum of the sun-spot cycle. Sir G. B. Airy has obtained similar results from the Greenwich observations. In 1871 E. J. Stone examined the temperature observations recorded during thirty years at the Cape of Good Hope, and came to the conclusion that the same cause which leads to an excess of mean annual temperature at the Cape leads equally to a dissipation of sun-spots. Dr W. Köppen in 1873 discussed at great length the connexion between sun-spots and terrestrial temperature, and found that in the tropics the maximum temperature occurs fully a year before the minimum of sun-spots, while in the zones beyond the tropics it occurs two years after the minimum. The regularity and magnitude of the temperature wave are most strongly marked in the tropics.

112. The evidence now given appears at first sight to be antagonistic to that derived from the other elements both of magnetism and meteorology, and to lead us to conclude that the sun heats us most when there are fewest spots on its surface. This conclusion will not, however, be strengthened if we examine the subject with greater minuteness.

[1] *Nature*, November 25 and December 2, 1880.
[2] *Nature*, March 18, 1880.
[3] *Ingenieur Zeitschrift*, 1873.
[4] *Ueber die Beziehungen der Sonnenflecken Periode zu den Magnetischen- und Meteorologischen Erscheinungen der Erde*, Haarlem, 1878.
[5] *Br. Assoc. Reports*, 1872.
[6] A. Poëy, *Sur les Rapports entre les Taches Solaires et les Ouragans des Antilles de l'Atlantique-Nord, et de l'Océan Indien Sud.*

Scientifically we may regard the earth as an engine, of which the sun is the furnace, the equatorial regions the boiler, and the polar regions the condenser. Now this engine may be supposed to work in the following manner. Hot air and vapour are carried along the upper regions of the atmosphere from the equator to the poles by means of the anti-trade winds, while in return the cold polar air is carried along the surface of the earth from the poles to the equator, forming what is known as the trade-winds. Whenever the sun's heat is most powerful both trades and anti-trades should be most powerful likewise. But we live in the trades rather than in the anti-trades—in the surface currents, and not in the upper currents of the earth's atmosphere. When, therefore, the sun is most powerful is it not possible that we might have a particularly strong and cold polar current blowing about us? The same thing would happen in the case of a furnace-fire; the stronger the fire the more powerful the hot draught up the chimney, the more powerful also the cold draught from without along the floor of the room. It might thus follow that a man standing in the furnace-room near the door might be chilled rather than heated when the furnace itself was roaring loudest. In fact temperature is a phenomenon due to many causes. Thus a low temperature may be due (1) to a deficiency in solar power, (2) to a clouded sky, (3) to cold rain, (4) to cold winds, (5) to cold water and ice, (6) to cold produced by evaporation, (7) to cold produced by radiation into space.

Blanford has recently shown that at certain Indian stations a low mean temperature occurs when there is an unusually large rainfall and a great amount of clouds, a result in accordance with the conclusions previously enunciated by Professor Piazzi Smyth. Records of maximum and minimum temperature must not therefore be too closely associated with a maximum and minimum of solar power.

113. Considerations of this nature have induced Stewart to imagine (*Nature*, June 16, 1881) that the true connexion between sun-spots and terrestrial temperature is more likely to be discovered by a study of short-period inequalities of sun-spots than by that of the eleven-year period in which there is time enough to change the hygrometric state of the atmosphere and the whole convection system of the earth. He has accordingly discussed at some length two prominent sun-spot inequalities of short period (about twenty-four days), and endeavoured to see in what way they affect terrestrial temperature. From this it appears that a rapid increase of sun-spots is followed in a day or two by an increase of the diurnal temperature range at Toronto. Now an increase of diurnal temperature range most probably denotes an increase of solar energy, and we are thus led to associate an increase of solar heat with a large development of spots. This, however, is a point which requires further investigation.

114. *General Conclusion.*—On the whole we may conclude that the meteorological motions and processes of the earth are probably most active at times of maximum sun-spots, and that they agree with magnetical phenomena in representing the sun as most powerful on such occasions, although the evidence derived from meteorology is not so conclusive as that derived from magnetism.

Hypothetical Views regarding the Connexion between the State of the Sun and Terrestrial Magnetism.

115. *Principles of Discussion.*—In the following discussion we claim only to advance a working hypothesis, with the view of suggesting further inquiries into the subject of terrestrial magnetism. It seems therefore desirable that we should limit ourselves to such probable or possible causes as are known to exist and to operate on the earth. These various agents or causes will be described, and we shall endeavour to show that converging lines of evidence point in several cases to certain of these as being most likely to produce that particular type of effect which is exhibited in terrestrial magnetism. This course will in our view most readily suggest further inquiries with the view of confirming or disproving the various points of this working hypothesis. Believing that the introduction of any unknown cause can only be justified when known causes have been found insufficient to account for the phenomena in question, we have not advocated any direct magnetic action of the sun upon the earth. We have refrained from this for two reasons,—first, because from what we now know of the sun it appears to us unlikely that it should exercise an influence of this nature upon the earth, since a body at a high temperature possessing very strong magnetic properties is unknown to us; and, secondly, we shall see further on that such an influence will not explain the best-understood magnetic changes, nor is there in our opinion any magnetic phenomenon for the explanation of which it appears absolutely necessary to resort to this hypothesis. In fine, without presuming to deny the possibility of unknown influences of this nature, it does not appear to us that the time has yet arrived when we are called upon to resort to such as necessary aids to the discovery of further truth.

116. *Nature of Solar Variations.*—It is quite certain that there is a variability in the visible appearance of the sun's disk, which exhibits sometimes a comparatively large amount of spotted area while on other occasions it is entirely free from spots. Now it has been remarked by Thomson that were the sun an incandescent solid its surface would become cool in a few minutes. The astonishing property which our luminary possesses of pouring out continuously a vast amount of radiant energy must unquestionably depend upon machinery of great power by means of which fresh hot particles are rapidly brought from the interior to the surface, while those particles which have given out their light and heat are rapidly hurried downwards to be recruited from the great storehouse of heat in the sun's centre. In fine, a gigantic system of convection currents of this nature forms the essential condition without which the sun would not be able to continue shining as it does.

The mottled appearance of the sun's disk as seen through a telescope denotes no doubt the existence of a vast system of ascending and descending currents, the hot matter rising from beneath being denoted by the brighter portions and the cold matter descending from above by the darker portions of the structure. On certain occasions and in certain regions of the sun the scale of these phenomena is greatly increased, and we have a huge up-rush of bright and a corresponding down-rush of black matter—in fine, the well-known sun-spot with its bright faculous appendages. Whenever sun-spots are very frequent we should therefore expect the convection system of the sun to be particularly powerful, and the great velocity and size of the red flames or the higher portions of the convection system observed around the sun's limb on such occasions confirm us in this supposition. And if the convection system of the sun be particularly powerful when there are most spots on its surface, it would seem to follow that the radiation from our luminary should on such occasions be particularly powerful also. The spectroscope leads us to the same conclusion. It would appear from the observations of Lockyer and others that at times of maximum sun-spots certain definite regions of the sun when examined spectroscopically present all the appearances of a very high temperature.

We are unable to confirm these conclusions by direct observations of the sun's heating power. Actinometrical determinations have not yet been made with sufficient accuracy and persistence to decide this point experimentally. We have, however, evidence of an indirect nature derived from terrestrial magnetism and meteorology all tending to make us think that the sun is most powerful during times of maximum sun-spots. We have seen that on such occasions the solar influence upon the magnetism of the earth is peculiarly powerful in more than one way, and that its influence on meteorology is then peculiarly powerful also, although we are not so certain of this latter fact as of the former.

We may therefore take it to be most probable that the sun is most powerful at times of maximum sun-spots, and proceed from this basis to propound the two following questions:—in the first place, what is the nature of the solar influence upon terrestrial magnetism? and, secondly, why is this influence so much more easily perceived than certain forms of solar influence upon meteorology?

117. *Diurnal Magnetic Variations—Hypotheses regarding them.*—The various speculators on the cause of these phenomena have ranged over the whole field of likely explanations. (1) It has been supposed that the sun acts directly as a magnet upon the magnetism of the earth. (2) It has been imagined that convection currents established by the sun's heating influence in the upper regions of the atmosphere are to be regarded as conductors moving across lines of magnetic force, and are thus the vehicle of electric currents which act upon the magnet. (3) Faraday, reasoning from his discovery that oxygen is paramagnetic, and becomes weaker in its power when heated, and stronger when cooled, supposed that the sun by heating certain portions of the atmosphere renders them less magnetic while others, not subjected to any heating influence are rendered more magnetic. The action is equivalent to a displacement by means of the sun of the magnetic matter of the earth, and involves a displacement of the lines of force. Here too the solar action is associated with the great mass of the atmosphere. (4) It has been supposed by Christie and by De la Rive that the heat of the sun produces in the atmosphere and in the earth thermo-electric currents which produce the daily magnetic variations. It is not easy to perceive how we could have thermo-electric currents in the upper regions of the atmosphere, but there is no obvious objection to the generation of such currents in the crust of the earth. Thus the first hypothesis has no reference to the atmosphere whatever; the second deals with the upper atmospheric regions, the third with the great body of the atmosphere, while the fourth, as we have ventured to modify it, has reference to the crust of the earth.

118. *Discussion of these Hypotheses.*—Dr Lloyd and Mr C. Chambers[1] have both shown that direct solar magnetic action will not account for the peculiarities of the diurnal magnetic variation. Again (§ 48) we have strong evidence that changes in the range of the daily magnetic variation lag behind corresponding solar changes in point of time. Now this kind of behaviour is inconsistent with direct magnetic action, and points rather to an indirect magnetic effect caused by the radiant energy of the sun.

[1] *Proc. Royal Irish Academy*, February 22, 1858; *Phil. Trans.*, 1863.

119. Let us therefore dismiss the hypothesis of direct action and consider that of Faraday. We know both from observations of the declination and horizontal force (*Proc. Roy. Soc.*, March 22, 1877, and *Phil. Trans.*, 1880, p. 541) that the action of the sun in producing diurnal variations of these elements is one and a half times as powerful at epochs of maximum as it is at epochs of minimum sun-spot frequency. It is hardly credible that there should be such a great difference on these occasions in the sun's heating effect upon the great bulk of the atmosphere. Meteorologists have never observed such a difference, nor is there any marked corresponding inequality of diurnal temperature range. Meteorological evidence is thus against the diurnal magnetic changes being due to the heating up by the sun of the great mass of oxygen which constitutes the magnetic portion of the earth's atmosphere. Again, as there is a preponderance of hot oxygen in the northern hemisphere during the June and in the southern hemisphere during the December solstice, there ought according to this theory to be a well-marked annual variation of the magnetism of the earth, the northern hemisphere being at the same time differently affected from the southern. But there are no traces of such a phenomenon, the annual and semi-annual variations which we have already described (§§ 64–67) being of quite a different nature, and none of them very large.

120. Precisely the same objections apply with even greater force to the fourth hypothesis. It seems impossible to allow that any heating effect of the crust of the earth caused by the sun can be one and a half times as great at epochs of maximum as it is at epochs of minimum sun-spot frequency.

121. We are thus driven by the method of exhaustions to look to the upper regions of the earth's atmosphere as the most probable seat of the solar influence in producing diurnal magnetic changes, and it need hardly be said that the only conceivable magnetic cause capable of operating in such regions must be an electric current. Now we know from our study of the aurora that there are such currents in these regions—continuous near the pole and occasional in lower latitudes. A good deal has been said about the difficulty of imagining a daily set of currents to be generated in regions of such imperfect conductivity, but we shall see by and by (§ 134) that there seems ground for imagining that their conductivity may be much greater than has hitherto been supposed.

122. *Analogies between the Meteorological and Magnetical Systems of the Earth.*—We have in the first place a zone of maximum terrestrial temperature, the middle line of which is nearly coincident not only with the geographical but likewise with the magnetical equator. Again, there are possibly in the northern hemisphere two poles of greatest cold, which possibly do not greatly differ in position from those spots which we have called magnetic poles or foci. About the southern hemisphere we have no information.

Furthermore we believe that the hot air is carried from the zone of greatest heat to the place or places of greatest cold by means, no doubt, of the return trades which blow in the upper atmospheric regions. The hot air divides at this zone, one part blowing northwards in the northern and another southwards in the southern hemisphere. Now this zone, from which the anti-trades divide, has an annual motion of its own, being found farthest north at the June solstice and farthest south at that of December. Probably too the northern system is strongest in June and the southern system in December. If we now turn to the solar-diurnal variation of magnetic declination, we find here also a northern and a southern system (§ 41), the type of the one being antagonistic to that of the other. We find also that the northern system is strongest in June and the southern system in December.

Again, it seems probable from what we have now said that the anti-trades, strictly speaking, have reference not to the geographical equator and poles but to the zone of maximum and the poles of minimum temperature. Now, turning once more to the diurnal oscillations of the declination needle, it seems probable that the directions east and west must be interpreted as having a reference not to the geographical but to the magnetical pole (§ 45).

These analogies must be taken for what they are worth. Our object in introducing them has reference to the previous discussion, from which we concluded that the magnetic influence of the sun is probably due to currents in the upper region of the atmosphere—the cause of which we were content to leave in abeyance. Now these analogies would lead us to suggest that this cause, whatever it is, may perhaps be found to be related to the convection system of the earth on the one hand and to the magnetic system on the other.

123. *Analogies between Meteorological and Magnetical Weather.*—These remarks are borne out by the further analogy which appears to subsist betwixt what we have termed meteorological and magnetical weather. Let us take the solar-diurnal variation of declination. Not only is this variation similar in form to the diurnal variation of atmospheric temperature (§ 37), but the ranges of the two have a similar annual variation. And, as the element of meteorological weather affects the orderly march of the temperature range, just so the element of magnetical weather affects the orderly march of the declination range.

Furthermore, just as temperature-range weather progresses from west to east (§ 52), so declination-range weather would seem to progress in the same direction as the other (§ 52) although at a greater rate. It will doubtless require a more extended investigation to make us quite sure of this latter point; nevertheless we do not perceive the validity of the objection that is sometimes made to the hypothesis of progress in magnetic weather on the ground that magnetic influences are known to affect all portions of the globe simultaneously. It will, we think, be perceived that in the above statement no supposition whatever is made with respect to the rate of propagation of a magnetic influence through the earth; this may be instantaneous or it may not. It is supposed that we have here a travelling cause of excitement, say a travelling cause of currents in the upper regions of the atmosphere which progresses from west to east and always produces its most marked effect above those regions where it passes—just as the sun itself in passing from east to west produces a magnetic effect the various phases of which travel from east to west with the sun which causes them. We think too that this hypothesis of travelling causes of magnetic change is strengthened by the facts observed by Capello and described in § 97.

124. If, however, the objection made to this hypothesis refers to the fact disclosed by Broun (§ 85) that changes of horizontal force appear to take place simultaneously at distant parts of the earth's surface, then we think that analogy should lead us not to deny the possibility of a travelling magnetic excitement, but rather to suggest the possibility of there being some meteorological influence which, like the magnetical one above mentioned, may be found to take place simultaneously at different parts of the earth's surface. Now Broun (*Proc. Roy. Soc.*, May 11, 1876) has given us preliminary evidence for supposing that there are simultaneous barometric variations. For instance, there was a barometric maximum at Hobart Town, Peking, the Cape, St Helena, Makerstoun, Singapore, Madras, Simla, Ekaterinburg, and Bogoslovsk about the end of March or first day of April 1845. There appears to have been a simultaneous increase of the horizontal force of the earth at various stations much about the same time, and there also appears to have been a short-period maximum of spots on the solar surface. Broun has likewise registered simultaneous barometric variations at Singapore, Madras, and Simla, for the first three months of 1845. From these it would seem that simultaneous barometric maxima are possibly coincident with rapidly increasing sun-spot areas.

Again is it not absolutely certain that if there is a sudden increase of solar power this must mean an increase of heat communicated to the earth, although it may be difficult or even impossible to obtain experimental evidence of such a fact? All these are subjects which require further investigation.

125. *Further Remarks on the Solar-Diurnal Variation of Declination.*—In § 24 we have asked how far the action of the solar-diurnal force upon a freely-suspended magnet is due to currents acting directly upon the magnet and how far to a change produced in the magnetism of the earth. Some light appears to be thrown on this point by the behaviour of the needle at places near the magnetic pole where the dipping needle is nearly vertical. On opposite sides of this locality the declination needle points in opposite directions. Now suppose that we have a set of such needles placed all round this region. It seems a legitimate generalization from the observations described by Sabine (§ 45) to conclude that if we place ourselves above the centre of any of these needles at 8 A.M., and look towards its marked pole, we shall find it in every case deflected towards the right, while if we look towards the same pole at 2 P.M. we shall find it deflected to the left. Now if we imagine that at 8 A.M. there are above these magnets (in the upper atmospheric regions) electrical currents of which the horizontal components form a set of positive currents flowing from the pole on all sides, then by the known laws of such currents the marked pole of all these needles will be deflected towards the right. And if at 2 P.M. the resolved portions of such currents should be flowing towards the pole, then the marked poles of all these needles will be deflected towards the left. It thus appears that this peculiar magnetic behaviour might easily be explained by a hypothetical distribution of currents. And in fact in such regions we have indubitable evidence of the existence of currents in the upper regions of the atmosphere. On the other hand this behaviour could not easily be explained by the hypothesis of some definite temporary magnetic system set up by the solar influence in the earth, for in such a case we should imagine that similar poles of all the needles ought to be deflected towards the pole of this temporary system, which is not the case.

126. Another point for consideration is the possible complexity of the solar-diurnal variation. For we may imagine (1) that the sun acts in such a manner as to produce a diurnal variation; (2) it may also act like the moon (§ 94) and produce a semidiurnal variation; (3) these possible actions may be accompanied by induced currents in the upper regions of the atmosphere and in the crust of the earth; (4) it is possible that the sun's rays may affect these variations or some of them in the way in which Broun found that the lunar variation at Trevandrum was affected by the sun. It

was found by him that the lunar action was considerably increased when the sun was above the horizon of the place.

127. We have pointed out (§ 119) that, while there is a marked likeness in many respects between the diurnal variation of declination and that of atmospheric temperature, we have yet no long-period fluctuation of the diurnal range of temperature at all comparable in magnitude to the magnetic fluctuations. It does not, however, seem difficult to account for this difference if we imagine that the magnetic fluctuations take their origin in the upper atmospheric regions, while the temperature fluctuations are due to the lower regions of the earth's atmosphere. For, as the sun increases in power from times of minimum to times of maximum sun-spot frequency, we may imagine that a continuously increasing amount of aqueous vapour will be taken into the earth's atmosphere.

Now the experiments of Tyndall and others induce us to think that the air would under such circumstances become more and more opaque for certain rays of the sun, and thus a continuously decreasing proportion of the sun's heat would be able to penetrate into the lower atmospheric regions. This latter influence would therefore operate to cloak, perhaps to a considerable extent, the effect of the sun's increasing power; and this may very well be the reason why the temperature range at the earth's surface does not exhibit the same eleven-yearly inequality as the declination range.

128. There seems, however, reason to believe that if we go from long to short period inequalities there is a much greater similarity in the range of the magnetical and the meteorological changes (§ 113). The explanation seems to be that in the short-period changes the sun has not time to alter sensibly the constitution of the atmosphere, and hence the proportional increase of effect experienced in the upper atmospheric regions is more nearly the same as that experienced near the surface of the earth.

129. *Magnetic Disturbances.*—There is strong evidence that the most important disturbances break out very nearly simultaneously at widely different parts of the earth, and that they even affect both hemispheres at the same time. Very little, however, is known about the *modus operandi* of the forces concerned in producing such disturbances. For instance, it is not known whether a disturbance permanently affects the magnetic state of the earth, *e.g.*, whether one of the magnetic elements before a disturbance begins is sensibly different in value from what it is after the disturbance has ceased to exist. On the other hand we know (1) that disturbances break out on the very day when there are rapid changes taking place on the sun's surface (§ 83); (2) that they generally begin by momentarily increasing the horizontal force, but that the type quickly changes, so that during most disturbances the horizontal force is diminished (§ 86); (3) that large disturbances take place more particularly about the equinoxes, when, we have reason to believe, the horizontal force of the earth is at a minimum (§ 77). May we not possibly conclude from these habits of action that at times of disturbance the earth is magnetically in a delicate state of equilibrium, perhaps having more magnetism than its surroundings would strictly warrant, and being therefore inclined to part with some, and that a sudden increase of solar activity, tending, as such changes probably do, at first to exalt the magnetism of the earth, nevertheless destroys its magnetic balance and gives it ultimately the opportunity of parting with some of its magnetism? This can only be regarded as a speculation, inasmuch as we do not know whether or not a disturbance produces any permanent influence upon the magnetism of the earth.

130. *Auroras and Earth Currents.*—There is no doubt that these phenomena denote electric currents in the upper regions of the atmosphere and in the moist conducting crust of the earth. The point in dispute is with respect to the origin of such currents. Some are inclined to regard auroras as peculiar manifestations of atmospherical electricity in high latitudes, while others imagine that such displays are rather of the nature of induced currents generated by small but abrupt changes taking place in the magnetism of the earth. The advocates of the first view do not deny that currents taking place somehow in the upper atmospheric regions will have their conditions modified, to some extent at least, by the inducing influence of magnetic changes. Nor will the advocates of the induction hypothesis be disposed to deny the possibility or even the certainty that displays due to atmospherical electricity and not dissimilar to some kind of aurora take place in some region of the atmosphere. But the first party regard auroras rather as the cause than as the effect of magnetic changes, whereas the advocates of induction regard such displays rather as the effect than as the cause of changes somehow produced in the magnetism of the earth. And here it is desirable to remark that the advocates of the induction hypothesis take for granted the magnetism of the earth and the changes thereof as phenomena for which they do not profess to account, whereas unless we go to some absolutely unknown cause (and this is against our present programme) we must look to atmospherical electricity as likely to throw light upon the origin of terrestrial magnetism. We cannot therefore dispense with regarding atmospherical electricity as an agent which may have played an important part in the development of the present magnetical condition of the earth, but we are yet of opinion that, under the present state of things, the theory which holds by atmospheric electricity must largely be supplemented by the induction hypothesis if it is to explain the peculiarities in type or form of the phenomena which observation brings before us.

131. Professor Tait in his essay on thunderstorms attributes one kind of aurora to atmospherical electricity. Such an aurora is, he believes, the manifestation of almost continuous discharges, like those given by a Holtz machine in a vacuum tube. The cause is condensation of vapour going on very slowly in very large spaces of air. The electricity is due to previous contact of particles of air and vapour. The result is that the air-particles in the mixture in time acquire a definite difference of potential from those of vapour,—so that, when the latter aggregate, a misty region well charged is the result, and this discharges to the oppositely electrified air all round.

132. Again, Professor Stokes, without attempting to account for the origin of atmospherical electricity, has produced an hypothesis with the view of explaining the intimate connexion subsisting between auroral displays, earth currents, and magnetic changes on the one hand and outbursts of sun-spot activity on the other. His idea is that two somewhat distant atmospheric regions A and B are charged, let us say, with positive and negative electricity respectively; A induces in the ground below it a charge of negative, B a charge of positive electricity. At first things are held in this state: A cannot discharge either through the upper atmospheric regions to B or through the lower regions to the ground beneath it, while B is in a position precisely similar. Presently, however, an increase of the radiative power of the sun is produced. Such an increase would probably imply not merely an increase in general radiation but a particular increase in such actinic rays as are absorbed in the upper regions of the earth's atmosphere. The layer of atmosphere between A and B will therefore greedily absorb such rays, its temperature will rise, and, as is known to be the case for gases, the electrical conductivity of the stratum will be increased. A discharge will therefore ultimately take place in the upper regions between A and B; this will relieve the charges of negative and positive in the ground immediately beneath A and B, and these charges will therefore rush together through the ground, producing an earth current. This earth current will be in the opposite direction from the atmospheric current, and the two will combine to represent, virtually at least, if not absolutely, a closed circuit. This will of course affect the earth's magnetism and produce a disturbance.

133. This hypothesis certainly affords a good explanation of the promptness with which disturbances follow increased solar activity (§ 83). Unless we are to resort to some unknown cause it is difficult to think of any other possible explanation of this fact. Such an explanation appears too to receive corroboration from the fact (§ 97) that the lunar influence on the earth's magnetism as observed at Trevandrum is greater during the day than during the night,—greater possibly too at times of maximum than at times of minimum sun-spots. We are therefore disposed to accept this explanation of the way in which increased solar activity produces magnetic disturbance as the best that has been brought forward.

134. This does not, however, decide the disputed point how far these elevated currents are due to atmospherical electricity and how far to induction. The argument against the possibility of induced currents in these regions is derived from experiments with vacuum tubes, such as those recorded by Messrs De la Rue and Müller, which would seem to indicate that enormous differences of potential would be required to produce electrical currents in elevated regions, where the atmosphere is very rare.

Indeed, on account of these experiments, the measurements of the old observers, who sometimes assigned a height of more than 100 miles to the aurora, have been called in question, and it has been supposed against direct observation that these phenomena must always occur in regions much less elevated. It would appear too that such reasons were influential in determining Professor Stokes to regard the aurora as produced by atmospherical electricity which, as we know from ordinary lightning, presents us with enormous differences of potential; but it is to be remarked that he has carefully guarded himself against the possibility of laboratory experiments with vacuum tubes not being strictly analogous to that which takes place in the upper atmospheric regions. Now it would appear that recent experiments by Hittorf throw some doubt upon the strictness of this analogy. The high difference of potential required to force the current through vacuum tubes is, according to this observer, due in great part if not entirely to the passage of the fluid from the terminal to the residual air of the tube, so that the potential requisite to pass a current through a tube of double length is not sensibly greater than that required for a tube of single length. The whole subject is one which demands further investigation; meanwhile we are not disposed to assert the impossibility of induction currents taking place in the upper atmospheric regions.

135. Let us now consider whether the form or type of the earth currents observed during disturbances favours the presence of induction to any sensible extent. The remarks of Dr Lloyd already quoted (§ 93), which are confirmed by the Greenwich observations, seem to be decisive in this respect. These may be interpreted in

the following manner. In a magnetic disturbance we have frequently a general displacement of the various elements—the horizontal force, for instance; now on the curve which represents this slow but considerable displacement a large number of comparatively small but very abrupt changes are superimposed. These latter appearances are invariably accompanied by quick and strong alternations from positive to negative of the earth currents, while the former slow motion, although it may be of large range, hardly appears to have any galvanic equivalent at all. This would appear to favour the induction hypothesis, according to which small but abrupt magnetic changes should give rise to strong earth currents alternately positive and negative without reference to the position of the magnet above or below its normal at the time.

136. Another fact bearing upon this hypothesis is that mentioned in § 88. From this it would appear that on ordinary occasions the curves recording the progress of the declination needle at Kew and Stonyhurst are as nearly as possible identical, but on occasions of disturbance the range at Stonyhurst is greater than that at Kew by an amount not apparently depending so much on the magnitude of the disturbance as on its abruptness. The introduction of the element of abruptness would appear to be in favour of the mixing up to some extent of induced currents with the phenomena in question.

137. Sir George Airy has not been able to detect any resemblance in form between the regular diurnal progress of the magnet and that of the earth currents. It seems, however, possible that the peaks and hollows alluded to in § 73 may form an important and integral part of the daily magnetic movement, and there even appears to be some evidence that the diurnal progress of the earth currents bears a nearer resemblance to that of the peaks and hollows than it does to the progress of the smoother curve which is usually held to represent the diurnal variation. But this is a question which can only be decided by more prolonged investigations.

138. To conclude, there can be no doubt that at times of great magnetic disturbance we have currents in the upper atmospheric regions and in the crust of the earth which, so far as we can see, must either be due to atmospherical electricity or to induction, or to a mixture of both. The proportions of this mixture can only be decided by further inquiry and by the multiplication of stations where atmospherical electricity and earth currents may be observed. It ought to be mentioned that the experience of the Kew observers, as far as this extends, seems unfavourable to the hypothesis of a connexion between auroras and atmospheric electricity.

139. *Lunar-Semidiurnal Variation.*—From the fact observed by Broun (§ 98) that the moon's magnetic influence is as nearly as possible inversely proportional to the cube of the moon's distance from the earth, it is impossible to refrain from associating it either directly or indirectly with something having the type of tidal action, but in what way this influence operates we cannot tell. Is it possible that the earth currents observed by A. Adams (§ 101) are induction currents generated in the conducting crust of the earth by the magnetic change caused by the moon,—inasmuch as these currents were found by him to be strongest in one direction about the lunar hours 3 and 15, when the lunar-diurnal magnetic effect is changing most rapidly in one direction (§ 95), while they were found to be strongest in an opposite direction about the lunar hours 9 and 21, when the lunar-diurnal magnetic effect is changing most rapidly in an opposite direction?

140. We might perhaps expect from the analogy of the tides that the sun should possess a semidiurnal magnetic effect similar in type to that of the moon. Now Sir George Airy in his analysis of the earth currents observed at Greenwich (*Phil. Trans.*, 1870) during days of tranquil magnetism has detected in such currents a semidiurnal inequality having maxima in one direction at solar hours 3 and 15, while it has maxima in the opposite direction at solar hours 9 and 21. The reference to solar hours in this inequality is thus precisely similar to that which the inequality observed by Adams bears to lunar hours.

141. If there are induced currents of this nature in the crust of the earth, we might naturally suppose that there will be corresponding currents in the upper regions of the earth's atmosphere, and in accordance with the suggestion made by Professor Stokes (§ 132) we might perhaps suppose that these currents will be strongest when the upper atmospheric regions are heated by the sun and thereby rendered better conductors. Is it not possible to suppose that the influence of daylight upon the lunar magnetic effect discovered by Broun (§ 97) may be due to this cause, and may it not also induce us to recognize the possibility of a maximum lunar influence (§ 99) at times of maximum sun-spots, when there is reason to believe that solar radiation is most powerful?

142. *Secular Variation.*—Sabine and Walker are agreed in regarding this variation as cosmical in its origin, and they are apparently of opinion that it is caused by some change in the condition of the sun. It seems difficult if not impossible to attribute it to anything else, since the terella of Halley cannot be now regarded as having a physical existence. Again it is more than possible—it is probable—that there are solar variations of much longer period than eleven years. On the other hand the evidence given in § 81, tending to show that an access of sun-spots produces a change in the magnetic state of the earth consistent with the hypothesis that the magnetizing power of the sun has then been augmented, requires to be confirmed by more observations; and even then it is certain that this magnetic change produced by a considerable change in spotted area is extremely small. We cannot therefore regard the very large secular magnetic change as due to a non-cumulative magnetic influence of some long-continued solar variation; nor does it seem possible to attribute the change to solar influence at all unless we regard this influence as producing results of a cumulative nature.

It is possible, however, to regard solar influence as producing a cumulative effect in one of two ways, or by a combination of both. For (1) time is necessarily an element in any influence acting upon the hard-iron system of the earth—presuming the earth to possess such a system. There are in fact indications in the results of § 82 that a system of this kind is perhaps connected with the American pole; yet, even allowing the influence of time, it seems difficult to account for the peculiarities of the secular variation by an hypothesis of this nature. But (2) any long-continued variation of solar power would no doubt act cumulatively in producing an increase or diminution of the large ice-fields round the poles of the earth. In the course of time this cumulative change in the extent and disposition of these might perceptibly alter the distribution of the convection currents of the earth—and these, according to the views herein indicated, might in their turn perceptibly alter the earth's magnetic system.

143. *Concluding Remarks.*—If we agree to look for an explanation of terrestrial magnetism and its changes to strictly terrestrial processes, we may derive some assistance in our search from such considerations connected with symmetry as enable us, for example, at once to perceive that when two perfectly similar things are rubbed together we cannot have electrical separation, because there is no reason why the one should be positively and the other negatively electrified. Suppose then that an observer stands at the equator and looks towards the north, and then turns his back upon the north and looks towards the south. In the first position let him regard the northern system of meteorological processes and motions, and in the second the southern. Now if symmetry obtained absolutely in these systems—that is to say, if the observer, whether he regarded the northern or the southern system of things, had in either case precisely similar phenomena at his right hand and at his left—then we should see no reason why the earth should be a magnet, or why one hemisphere should be the seat of magnetism of the one kind rather than of the other. If then we regard meteorological processes and motions as being in some way the cause of terrestrial magnetism, we must direct our attention to that peculiar element which causes a want of perfect symmetry such as we have described in meteorological phenomena. This element can hardly be anything else than the rotation of the earth, which is from left to right to an observer facing the north, but from right to left to an observer facing the south.

144. Now if we look upon the terrestrial meteorological system modified by the earth's rotation as having produced somehow in the past the magnetic state of the earth, it seems most natural to regard the system which formerly produced this magnetic state as being likewise that which at present maintains it in its efficiency, and which also accounts for the various magnetic changes which take place. It would seem therefore that terrestrial meteorology and terrestrial magnetism are probably cognate subjects, and that they ought to be studied together in the well-founded hope that the phenomena of the one will help us to explain those of the other.

Furthermore, if these meteorological processes—deriving their one-sided character from the earth's rotation—are to be regarded as accounting not only for the origin but for the maintenance of the earth's magnetic system, we can hardly fail to imagine that these processes must derive part of the energy which they exhibit from that of the earth's rotation. Tidal energy we know is derived from this source; but we must likewise regard part of the energy displayed in convection currents whether in the air or in the ocean as derived no doubt from the same source. And we may perhaps allow that in the phenomena of tidal action, as well as in those of convection currents of the air and ocean, there may be, not merely a transmutation of actual energy directly through friction into heat, but likewise a transmutation of it, ultimately perhaps into heat, but first through the intermediate agency of electrical currents which serve to maintain the magnetic state of the earth and to produce magnetic changes.

Now if this be the case, if there be a large and complicated system of tidal and convection currents all tending to change the rotative energy of the earth ultimately into heat, whether directly through friction or indirectly through the medium of electricity, it is surely impossible with the present state of our knowledge to calculate with the smallest pretensions to accuracy at what rate this transmutation is taking place, and hence at what rate the velocity of the earth's rotation is being slowly diminished. (B. S.)

METHODISM

I. Wesleyan Methodism.

THE history of Wesleyan Methodism embraces—(1) the Methodism of Oxford, which was strictly Anglican and rigidly rubrical, though it was also more than rubrical; (2) the evangelical Methodism of the Wesleys after their conversion (in 1738), of which the Wesleyan doctrines of conversion and sanctification were the manifesto and inspiration, while preaching and the class-meeting were the great motive and organizing forces,—a movement which before Wesley's death had developed into a form containing, at least in embryo, all the elements of a distinct church organization, although in its general designation and deliberate claims it purported to be only an unattached spiritual society; and (3) Wesleyan Methodism since the death of Wesley, which, by steps at first rapid and afterwards, though leisurely, distinct and consecutive, assumed an independent position, and has grown into complete development as a church.

1. *Oxford Methodism.*—This began in November 1729, when John Wesley, returning to Oxford from Lincolnshire, where he had been serving his father as curate, found that his brother Charles, then at Christ Church, had induced a few other students to join him in observing weekly communion. John Wesley's accession lent weight and character to the infant association. Their first bond of association, besides the weekly communion, was the common study of the Greek Testament, with which they joined regular fasting, the observance of stated hours for private devotion, the visitation of the sick, of the poor, and of prisoners, and the instruction of neglected children. They never themselves adopted any common designation, but of the variety of derisive names they received from outsiders that of "Methodists" prevailed,—a sobriquet the fitness of which, indeed, as descriptive of one unchanging and inseparable feature of Wesley's character (which he impressed also on his followers), was undeniable.

This first Oxford Methodism was very churchly. Between 1733 and 1735, however, a new phase was developed. Its adherents became increasingly patristic in their sympathies and tendencies, and Wesley came much under the influence of William Law. In regard to this period of his history, Wesley himself says that he

> "Bent the bow too far, by making antiquity a coordinate, rather than a subordinate, rule with Scripture, by admitting several doubtful writings, by extending antiquity too far, by believing more practices to have been universal in the ancient church than ever were so, by not considering that the decrees of a provincial synod could bind only that province, and the decrees of a general synod only those provinces, whose representatives met therein, that most of those decrees were adapted to particular times and occasions, and, consequently, when those occasions ceased, must cease to bind even those provinces."

It was in 1736, during his residence in Georgia, whither he had gone as a missionary of the Propagation Society, that he learnt those lessons. Notwithstanding his ascetic severity and his rubrical punctilios, the foundations of his High-Churchmanship were gradually giving way. When he returned to England he had already accepted the doctrine of "salvation by faith," although he had not as yet learned that view of the nature of faith which he was afterwards to teach for half a century. He had, however, as in the journal of his homeward voyage he tells us, learned, "in the ends of the earth," that he "who went to America to convert others was never himself converted to God." In this result his Oxford Methodism came to an end.

The original Methodism of Oxford never at any one time seems to have numbered as many as thirty adherents. There was a set called "Methodists," but there was no organization, no common bond of special doctrine or of discipline; there were habits and usages mutually agreed upon, but there was no official authority, only personal influence. The general features of the fraternity, if fraternity it may be called, seem to suggest closer analogies with the "Tractarian" school in its earlier stages than with anything else in modern history, and the personal ascendency of John Wesley may remind us in some measure of the influence exercised a century later by J. H. Newman. There was no more any germ of permanent organization in the Oxford Methodism of 1735 than in the patristic and "Tractarian" school of Oxford of 1833.[1]

2. *Methodism after Wesley's Conversion.*—John Wesley landed at Deal, on his return from Georgia, on February 1, 1738. His journals on the homeward voyage, says Miss Wedgwood,[2] "chronicle for us that deep dissatisfaction which is felt whenever an earnest nature wakes up to the incompleteness of a traditional religion; and his after life, compared with his two years in Georgia, makes it evident that he passed at this time into a new spiritual region." . . . . . "By Peter Böhler,[3] in the hands of the great God," he writes in his journal, "I was, on March 5, fully convinced of the want of that faith whereby we are saved." This "conviction" was followed on March 24 of the same year (1738) by his "conversion."

Like most good men of that age in England, Wesley, before he came under the influence of his Moravian teacher, had regarded faith as a union of intellectual belief and of voluntary self-submission—the belief of the creeds and submission to the laws of Christ and to the rules and services of the church, acted out day by day and hour by hour, in all the prescribed means and services of the church and in the general duties of life. From this conception of faith the element of the supernatural was wanting, and equally that of personal trust for salvation on the atonement of Christ. The work of Böhler was to convince Wesley that such faith as this, even though there might be more or less of divine influence unconsciously mingling with its attainment and exercise, was essentially nothing else than an intellectual and moral act or habit, a natural operation and result altogether different from the true spiritual faith of a Christian. This conviction led him a few days afterwards to stand up at the house of the Rev. Mr Hutton, College Street, Westminster, and declare that five days before he had not been a Christian. When warned not thus to despise the benefits of sacramental grace, he rejoined, "When we renounce everything but faith and get into Christ, then, and not till then, have we reason to believe that we are Christians." It is true that for several years after this he remained High-Church in

[1] One evidence of this is to be found in the early and wide divergence of the various members of the Oxford Methodist company, after their brief association at the university came to an end. We know which way the Wesleys went; we know also the separate path that their friend Whitefield made for himself. John Clayton, the Jacobite churchman, settled at Manchester, renounced the Wesleys after they began their evangelical movement, and remained an unbending High-Churchman to the end. Benjamin Ingham became a great evangelist in Yorkshire, founded societies, and, with his societies or churches, took the decisive step of leaving the Church of England and embracing the position of avowed Dissent. The saintly Gambold, a poet as well as a theologian and preacher, became a Moravian bishop. James Hervey was in after life a famous evangelical clergyman, holding "Low" and Calvinistic views. These were the chief of the Methodists of Oxford.

[2] *John Wesley and the Evangelical Reaction of the 18th Century.*

[3] A disciple of Zinzendorf, then in England on his way to America.

some of his principles and opinions, but nevertheless his ritualism was dead at its roots.

This experience also made Wesley an evangelist. He had a forgotten gospel to preach,—the gospel by which men were to be converted, as he had been, and to be made "new creatures." And this result, this new birth, was not dependent on any churchly form or ordinance, on any priestly prerogative or service, or on any sacramental grace or influence. To raise up, accordingly, by his preaching and personal influence, a body of converted men, who should themselves become witnesses of the same truth by which he had been saved, was henceforth to be Wesley's life-work. This was the inspiration under which he became a great preacher; this also made him an organizer of his living witnesses into classes and societies. In the pulpit was the preaching power; in the class-room was the private and personal influence. The vital link between the pulpit and the class meeting was the doctrine and experience of "conversion." Thus Wesleyan Methodism is derived, not from Wesley the ritualist, but from Wesley the evangelist.

Wesley's doctrines offended the clergy. His popularity as a preacher alarmed them. The churches were soon shut against him. He attended the religious meetings—on a Church of England basis—which had existed in London and elsewhere for fifty years, so far as these were still open to him, the Moravian meetings, and meetings in the rooms of private friends, but these were quite insufficient for the zeal and energy of himself and his brother, who had been "converted" a few days before himself. Accordingly, in 1739, he followed the example set by Whitefield, and preached in the open air to immense crowds. In the same year also he yielded to the urgency of his followers and to the pressure of circumstances, and, becoming possessed of an old building called "the Foundery," in Moorfields, transformed it into a meeting-house. Here large congregations came together to hear the brothers. About the same time, in Bristol and the neighbouring colliery district of Kingswood, he found himself obliged, not a little against his will, to become the owner of premises for the purpose of public preaching and religious meetings. Here was the beginning of that vast growth of preaching-houses and meeting-rooms, all of them for nearly fifty years settled on Wesley himself, which, never having in any way belonged to the Church of England, became, through Wesley, the possession of the Methodist Connexion.

The religious societies through which the Wesleys, after their conversion, exercised at first their spiritual influence were in part, as has been intimated, Moravian,—that in Fetter Lane, of which the rules were drawn up by Wesley himself in 1738 (May 1), being the chief of these,—and in part societies in connexion with the Church of England, the successors of those which sprang up in the last years of the Stuarts, as if to compensate for the decay of Puritanism within the church. In 1739, however, a strong leaven of antinomian quietism gained entrance among the Moravians of England (Böhler himself having left for America in the spring of 1738); and Wesley, after vainly contending for a time against this corruption, found it necessary formally to separate from them, and to establish a society of his own, for which a place of meeting was already provided at the Foundery. This was the first society under the direct control of Wesley, and herein was the actual and vital beginning of the Wesleyan Methodist Society, that is, of Wesleyan Methodism. Hence the Wesleyans celebrated their centenary in 1839. It was not, however, till 1743 that Wesley published the Rules of his Society. By that time not a few other local societies had been added to that at the Foundry, the three chief centres being London, Bristol, and Newcastle. Hence Wesley called his Society, when he published the "Rules" in 1743, the "United Societies." His brother's name was joined with his own at the foot of these Rules, in their second edition, dated May 1, 1743, and so remained in all later editions while Charles Wesley lived. Those Rules are still the rules of Wesleyan Methodism. Since Wesley's death they have not been altered. During his life only one change was made of any importance. In 1743 the offerings given weekly in the classes were for the poor, there being at that time no Conference and no itinerant preachers except the two brothers; after a few years the rules prescribed that the weekly contributions were to go "towards the support of the gospel." The Society is described as "a company of men having the form, and seeking the power, of godliness, united in order to pray together, to receive the word of exhortation, and to watch over one another in love, that they may help each other to work out their salvation." "The only condition previously required of those who desire admission into these societies" is "a desire to flee from the wrath to come, and to be saved from their sins." The customary contribution was a minimum of a penny a week or a shilling a quarter.

In 1739 these societies were not divided into "classes." But in 1742 this further step in organization was taken, and the change is recognized in the rules of 1743. Leaders were appointed to these classes, and became an order of spiritual helpers and subpastors, not ordained like lay elders in the Presbyterian churches, but, like them, filling up the interval between the pastors that "labour in the word and doctrine" and the members generally, and furnishing the main elements of a council which, in after years, grew up to be the disciplinary authority in every "society." In every society there was from the beginning a "steward" to take and give account of moneys received and expended. After a few years there were two distinct stewards, one being specially appointed to take care of the poor and the "poor's money," the other being, in general, the "society steward." And, finally,—though hardly, perhaps, during Wesley's lifetime,—in the larger societies there came to be two stewards of each description. The leaders and stewards together constituted "the leaders' meeting," of which, however, the complete circle of functions grew into use and into recognition only by degrees. The Rules of the Society, which are strict and searching, relate to worship, to conduct, and to the religious life, but do not once mention or refer to the Church of England, the parish church, or the parish clergy. The only authority at first was the personal authority of the two brothers, exercised either directly or by their official delegates. After years had passed away the leaders' meeting came to have an important jurisdiction and authority, but its rights and powers were neither defined nor recognized until after Wesley's death. From first to last there is no trace or colour of any Anglican character in the organization. Moravians or Dissenters might have entered the fellowship, and before long many did enter it who had either been Dissenters or, at any rate, had seldom or never entered a church. What would to-day be called the "unsectarian" character of his society was, indeed, in Wesley's view, one of its chief glories. All the time, however, this "unsectarian" society was only another "sect" in process of formation. Wesley for many years before his death had seen that, unless the rulers of the church should come to adopt in regard to his society a policy of liberal recognition, this might be the outcome of his life-work. And it would seem as if in his private confidences with himself he had come in the end at times to acquiesce in this result.

Still more decisive, however, was the third step in the

development of Wesley's "Society." The clergy not only excluded the Wesleys from their pulpits, but often repelled them and their converts from the Lord's Supper. This was first done on a large scale, and with a systematic harshness and persistency, at Bristol in 1740. Under these circumstances the brothers took thedecisive step of administering the sacrament to their societies themselves, in their own meeting-rooms, both at Bristol and at Kingswood. This practice having thus been established at Bristol, it was not likely that the original society at the Foundery would rest content without the like privilege, especially as some of the clergy in London acted in the same manner as those at Bristol. There were therefore at the Foundery also separate administrations. Here then, in 1740, were two—if we include Kingswood, three—separate local churches, formed, it is true, and both served and governed by ordained clergymen of the Church of England, but not belonging to that church or in any respect within its government. As thereafter during Wesley's life one of the brothers, or some cooperative or friendly clergyman, was almost always present in London and in Bristol for the administration of the sacraments, these communions, when once begun, were afterwards steadily maintained, the Lord's Supper being, as a rule, administered weekly. Both on Sundays and on week days full provision was made for all the spiritual wants of these "societies," apart altogether from the services of the Church of England. The only link by which the societies were connected with that church—and this was a link of sentiment, not an organic one—was that the ministers who served them were numbered among its "priests."

In 1741 Wesley entered upon his course of calling out lay preachers, who itinerated under his directions. To the societies founded and sustained with the aid of these preachers, who were entirely and absolutely under Wesley's personal control, the two brothers, in their extensive journeys, administered the sacraments as they were able. The helpers only ranked as laymen, many of them, indeed, being men of humble attainments and of unpolished ways. For the ordinary reception of the sacraments the societies in general were dependent on the parish clergy, who, however, not seldom repelled them from the Lord's table. So also for the ordinary opportunities of public worship they often had no resource but the parish church. The simple service in their preaching-room was, as Wesley himself insisted, defective, as a service of public worship, in some important particulars; besides which, the visits of the itinerants were usually, at least at first, few and far between. Wesley accordingly was urgent in his advices and injunctions that his societies generally should keep to their parish churches; but long before his death, especially as the itinerant preachers improved in quality and increased in number, there was a growing desire among the societies to have their own full Sunday services, and to have the sacraments administered by their own preachers. The development of these preachers into ministers, and of the societies into fully organized churches, was, if not the inevitable, at any rate the natural, result of the steps which Wesley took in order to carry on the work that was continually opening up before him.

In 1744 Wesley held his first Conference. The early Conferences were chiefly useful for the settlement of points of doctrine and discipline and for the examination and accrediting of fellow-labourers. They met yearly. Conferences were a necessity for Wesley, and became increasingly so as his work continued to grow upon him. It was inevitable also that the powers of the Conference, although for many years the Conference itself only existed as it were on sufferance, and only exercised any authority by the permission of its creator and head, should continually increase. The result was that in 1784 Wesley could no longer delay the legal constitution of the Conference, and that he was compelled, if he would provide for the perpetuation of his work, to take measures for vesting in trustees, for the use of "the people called Methodists," under the jurisdiction of the Conference as to the appointment of ministers and preachers, all the preaching places and trust property of the Connexion. The legal Conference was defined as consisting of one hundred itinerant preachers named by Wesley, and power was given to the "legal hundred" continually from the first to fill up the vacancies in their own number, to admit and expel preachers, and to station them from year to year, no preacher being allowed to remain more than three years in one station.

By this measure Wesley's work was consolidated into a distinct religious organization, having a legally corporate character and large property rights. And yet Wesley would not allow this great organization to be styled a "church." It was only a "society"—the "United Society"—the Society of "the people called Methodists"—the "Methodist Society." And of its members all who were not professed Dissenters were by him reckoned as belonging to the Church of England, although a large and increasing proportion of them seldom or never attended the services of that church. The explanation of this apparent inconsistency is that Wesley admitted none to be Dissenters except such as were so in the eye of the law—those who, "for conscience sake, refused to join in the services of the church or partake of the sacraments administered therein"—and that he interpreted "the Church of England" to mean, as he wrote to his brother Charles, "all the believers in England, except Papists and Dissenters, who have the word of God and the sacraments administered among them."

But Wesley was to carry his Society to a yet higher pitch of development, and one which made it still more difficult to distinguish its character from that of a distinct and separate church. In 1738 Wesley had been theoretically a High-Churchman. For some time even after he had entered upon his course of irregular and independent evangelism he continued to hold, in the abstract, High-Church views. But in 1746 he abandoned once for all his ecclesiastical High-Churchmanship, although he never became either a political or a latitudinarian Low-Churchman after the standard and manner of the 18th century. He relates in his journal under date January 20, 1746, how his views were revolutionized by reading Lord (Chancellor) King's account of the primitive church. From this time forward he consistently maintained that the "uninterrupted succession was a fable which no man ever did or could prove." One of the things taught him by Lord King's book was that the office of bishop was originally one and the same with that of presbyter; and the practical inference which Wesley drew was that he himself was a "Scriptural Episcopos," and that he had as much right as any primitive or missionary bishop to ordain ministers, as his representatives and helpers, who should administer the sacraments, instead of himself, to the societies which had placed themselves under his spiritual charge. This right, as he conceived it to be, he held in abeyance for nearly forty years, but at length he was constrained to exercise it, and, by so doing, in effect led the way towards making his Society a distinct and independent church.

In 1784, the American colonies having won their independence, it became necessary to organize a separate Methodism for America, where Methodist societies had existed for many years. Wesley gave formal ordination and letters of ordination to Dr Coke, already a presbyter of the Church of England, as superintendent (or bishop) for America, where Coke ordained Francis Asbury as presbyter and superintendent (or bishop), and Coke and Asbury together ordained the American preachers as presbyters. From that ordination dates the ecclesiastical commencement of American Episcopal Methodism—in which the bishops are only chief among the presbyters whom they superintend, superior in office but of the same order. The Episcopal Methodism of America represents today the largest aggregate of Protestant communicants and worshippers of the same ecclesiastical name to be found in any one nation in the world.

The following year (1785) Wesley ordained ministers for Scotland. There his societies were quite outside of the established Presbyterianism of the day, with its lukewarm "moderatism"; while the fervid sects which had seceded from the state church would hold no terms with Arminians like Wesley and his followers. Hence Wesley was compelled to make special provision for the administration of the sacraments in Scotland. He therefore ordained some of his ablest and most dignified preachers, was careful to give them formally in his correspondence the style and title of "Reverend," and appointed them to administer the sacraments north of the Tweed.

At length, in 1788, Wesley ordained a number of preachers (Mr Tyerman says seven) to assist him in administering the sacraments to the societies in England; and of these he ordained one (Alexander Mather) to be superintendent (or bishop), his brother Charles being now dead, and Dr Coke sometimes absent for long periods in America. The number of societies which demanded to have the sacraments administered to them in their own places of worship continually increased, and their claims were often too strong to be resisted, especially when the parish priest was either a public

opponent of the Methodists or a man of disreputable conduct. Before Wesley's death (in 1791) it would seem that there were more than a dozen of his preachers who had at different times, in Scotland or in England, been ordained to administer the sacraments.

The foregoing view of the development of Methodism as an organization, during the lifetime of its founder, will have conveyed a general idea of its structure and polity. There is one cardinal, though variable, element in its organization, however, of which there has as yet been no occasion to speak. The societies of Methodism—each of these consisting of one or more "classes"—were themselves grouped into circuits, each of which was placed under the care of one or more of Wesley's Conference preachers, who were called his "assistants" or "helpers," the assistant being the chief preacher of a circuit, and the helper being a colleague and subordinate. The "assistants" were directly responsible to Wesley, who had absolute power over them, and exercised it between the Conferences. The same power he equally possessed in the Conference, at the yearly meetings, but he made it a rule, during his later life, to take counsel with the Conference as to all matters of importance affecting the permanent status of the preachers personally, or relating to the societies and their government. He thus prepared the Connexion, both preachers and people, to accept the government and the legislative control of the Conference after his death.

At the time of Wesley's death there were in Great Britain, the Isle of Man, and the Channel Islands, 19 circuits, 227 preachers, and 57,562 members. In Ireland there were 29 circuits, 67 preachers, and 14,006 members. There were also 11 mission circuits in the West Indies and British America, 19 preachers, and 5300 members. The number of members in the United States was returned as 43,265.

It has already been explained that in connexion with each society there was a leaders' meeting, of which society stewards and poor stewards as well as leaders were members. It must here be added that each circuit had its quarterly meeting, of which, at first, only the society stewards and the general steward (or treasurer) for the circuit, in conjunction with the itinerant preachers, were necessary members. Leaders, however, in some circuits were very early, if not from the first, associated with the stewards in the quarterly meeting, or at least had liberty to attend. The quarterly meeting was not defined in Wesleyan Methodism until the year 1852. The leaders' meeting had no defined authority until some years after Wesley's death. Discipline, including the admission and expulsion of members, lay absolutely with the "assistant," subject only to appeal to Mr Wesley. Many years, however, before Wesley's death it had become the usage for the "assistant," or, in his absence, the "helper," his colleague, to consult the leaders' meeting as to important questions either of appointment to office or of discipline. As the consolidated "society" approached towards the character of a "church," the leaders' meeting began to acquire the character and functions of a church court, and private members to be treated, in regard to matters of discipline, as having a status and rights which might be pleaded before such a "court." The rights, indeed, which, soon after Wesley's death, were guaranteed to leaders' meetings and members of society had, there can be no doubt, so far grown up, before his death, as to be generally recognized as undeniable.

"Bands" were a marked feature in early Methodism, but in later years were allowed, at least in their original form, to fall out of use. There is no reference to them in the "Minutes of Conference" after 1768, although till after Wesley's death they held a place in the oldest and largest societies. Originally there were usually in each considerable society four bands, the members of which were collected from the various society classes—one band composed of married and another of unmarried men, one of married and another of unmarried women. All the members of society, however, were not of necessity members of bands. Some maturity of experience was expected, and it was the responsibility of the "assistant" to admit into band or to exclude from band. After Mr Wesley's death, where "bands" so called were kept up, they lost their private character, and became weekly fellowship meetings for the society.

The "love-feast" was a meeting the idea of which was borrowed from the Moravians, but which was also regarded as reviving the primitive institute of the *agape*. In the love-feast the members of different societies come together for a collective fellowship meeting. One feature of the meeting—a memory of the primitive *agape*—is that all present eat a small portion of bread or cake and drink of water in common.

It may be supposed that in such a system as Methodism a large number of preachers and exhorters, from all the social grades included within the societies, could not but be continually raised up. These, during Wesley's life, acted entirely under the directions of the assistant, and were by him admitted or excluded, subject to an appeal to Wesley. Once a quarter—often in conjunction with the circuit quarterly meeting—a meeting of these local lay helpers, called "local preachers," was held for mutual consultation and arrangement, and to examine and accredit candidates for the office.

3. *Wesleyan Methodism after Wesley's Death* (1791).—When Wesley died the Conference remained as the bond of union and fountain of authority for the Connexion. But between the meetings of Conference Wesley had acted as patriarch and visitor with summary and supreme jurisdiction. The first need to be supplied after his death was an authority for the discharge of this particular function. In America Wesley had organized a system of bishops (presbyter-bishops), presbyters or elders, and deacons or ministers on probation. Among some of those preachers who had been most intimate with Wesley there was a conviction that his own judgment would have approved such a plan for England. No document, however, remains to show that such was his desire. The only request he left behind him for the Conference to respect was one which rather looked in another direction—the well-known letter produced before the Conference on its first meeting after his death by his friend and personal attendant, Mr Bradford, in which he begged the members of the legal hundred to assume no advantage over the other preachers in any respect. The preachers, accordingly, in their first Conference after Wesley's death, instead of appointing bishops, each with his diocese or province, divided the country into districts, and appointed district committees to have all power of discipline and direction within the districts, subject only to an appeal to the Conference, all the preachers exercising equal rights also in the Conference, the "legal hundred" merely confirming and validating *pro forma* the resolutions and decisions of the whole-assembly.

At first the preachers stationed in the districts were instructed to elect their own chairmen, one for each district. But the plan was speedily changed, and the chairmen were elected each year by the whole Conference; and this method has been maintained ever since. The "district meetings"—as they are generally called—are still "committees" of the Conference, and have *ad interim* its power and responsibilities as to discipline and administration. Originally, they were composed exclusively of preachers, but before many years had passed circuit stewards and district lay officers came to be associated with the preachers during the transaction of all the business except such as was regarded as properly pastoral.

The relation of the Conference to the government of the Connexion having thus been determined, the question which next arose, and which occupied and indeed convulsed the Connexion for several years (1792–95), was that of the administration of the sacraments, especially of the Lord's Supper, to the societies. The societies generally insisted on their right to have the sacraments from their own preachers. Many of the wealthier members, however, and in particular a large number of the trustees of chapels, opposed these demands. At length, between 1794 and 1795, after more than one attempt at compromise had been made by the Conference, the feeling of the societies as against the trustees became too strong to be longer resisted, and accordingly at the Conference of 1795 the "plan of pacification" was adopted, the leading provision being that, wherever the majority of the trustees of any chapel, on the one hand, and the majority of the stewards and leaders, on the other, consented to the administration of the sacraments, they should be administered, but not in opposition to either the one or the other of these authorities. In England the Lord's Supper was always to be administered after the Episcopal form; in Scotland it might still, if necessary, be administered, as it had commonly been before, after the Presbyterian form. In any case, however, "full liberty was to be left to give out hymns and to use exhortation and extemporary prayer." The result was that within a generation the administration of the sacraments

to the societies came to be the universal rule. By this legislation the preachers assumed the powers of pastors, in accordance, however, only and always with the desire and choice of their flocks. No formal service or act of ordination was brought into use till forty years afterwards. All preachers on probation for the ministry, after the completion of their probation, were "received into full connexion" with the Conference, this reception implying investment with all pastoral prerogatives. Modern Methodism has developed more fully and conspicuously the pastoral idea.

No sooner was the sacramental controversy settled than the further question as to the position and rights of the laity came to the front in great force. A comparatively small party, led by Alexander Kilham, imported into the discussion ideas of a republican complexion, and demanded that the members in their individual capacity should be recognized as the direct basis of all power, that they should freely elect the leaders and stewards, that all distinction in Conference between ministers and laymen should be done away (elected laymen being sent as delegates from the circuits in equal number with the ministers), that the ministry should possess no official authority or pastoral prerogative, but should merely carry into effect the decisions of majorities in the different meetings. In the course of a very violent controversy which ensued, pamphlets and broadsheets, chiefly anonymous, from Kilham's pen, advocating his views and containing gross imputations on the ministers generally, and in particular on some not named but distinctly indicated, were disseminated through the societies. The writer was tried at the Conference of 1796, condemned for the publication of injurious and unjustifiable charges against his brethren, and by a unanimous vote expelled from the Conference. In the following year he founded the "New Connexion," the earliest of the organized secessions from Wesleyan Methodism.

Views much more moderate than Kilham's prevailed in the Connexion at large. At the Leeds Conference of 1797 the basis was laid of that system of balance between the prerogatives of the ministers and the rights of the laity which has been maintained in its principles ever since, and which, in reality, has governed the recent provisions (1877-78) for the admission of lay-representatives into the Conference not less than the former developments of Wesleyan Methodism. The admission of members into the society had, up to 1797, been entirely in the hands of the itinerant preachers,—that is, the "assistant," henceforth to be styled the "superintendent," and his "helpers." The new regulations, without interfering with the power of the ministers to admit members on trial, declared that "the leaders' meeting shall have a right to declare any person on trial improper to be received into society, and after such declaration the superintendent shall not admit such person into society"; also that "no person shall be expelled from the society for immorality till such immorality be proved at a leaders' meeting."[1] For the appointment of church officers (leaders and stewards) the following regulations were made, the second based on recognized usage, the first on general but not invariable practice:—

"1. No person shall be appointed a leader or steward, or be removed from his office, but in conjunction with the leaders' meeting, the nomination to be in the superintendent, and the approbation or disapprobation in the leaders' meeting.

"2. The former rule concerning local preachers is confirmed,—viz., that no man shall receive a plan as a local preacher, without the approbation of a local preachers' meeting."

The Conference at the same time made several provisions for carrying out the process, which had been going on for some years, of denuding itself of direct responsibility in regard to the disbursement of the Connexional funds. The principle was established that such matters were to be administered by the district committees acting in correspondence with the quarterly meetings of the circuits. It was also provided that circuits were not to be divided without the consent of the respective quarterly meetings; and, finally, it was resolved that, in the case of any new rule made by the Conference for the Connexion, its action within a circuit might be suspended for a year by the quarterly meeting, if it disapproved of the rule. If, however, the Conference, after twelve months' interval, still adhered to the new rule, it was to be binding on the whole Connexion.

The powers of district committees, as defined by former Conferences, were in 1797 confirmed and enhanced, special powers being given to special meetings of these committees convened when necessary to settle the affairs of a distracted circuit. In the same Conference all the principal rules of Methodism, in regard both to the ministers and the laity, were collected and (in a sense) codified, including the new regulations adopted that same year; and the whole, under the title "Large Minutes," was accepted as binding by the Conference, each minister being required to sign his acceptance individually. This compendium, itself based on one which had been prepared by Wesley, is still accepted by every Wesleyan minister on his ordination as containing the rules and principles to which he subscribes. During the sitting of this critical Conference at Leeds an assembly of delegates from bodies of trustees throughout the kingdom was simultaneously held. The form of the regulations enacted by the Conference was, to a considerable extent, determined by the nature and form of the requests made by this body of trustees. There was one request, however, which the Conference distinctly declined to grant—namely, that for lay delegation to the Conference. The Conference replied that they could not admit any but regular travelling preachers into their body, and preserve the system of Methodism entire, particularly the "itinerant plan." It was not until many years afterwards that anything was heard again as to this matter.

By the settlement now described the outlines of Methodism as an organized church were fairly completed. Many details have since been filled in, and many changes have been made in secondary arrangements, but the principles of development have remained unchanged. The Connexion after 1797 had a long unbroken period of peaceful progress. The effect of the "Kilhamite" separation, indeed, was after 1797 not greatly felt by the parent body. The number of Methodists in the United Kingdom in 1796, the year of Kilham's expulsion, was 95,226; in 1797 it was 99,519; in 1798 the New Connexion held its first Conference, and reported 5037 members, the number of the parent body being 101,682. Nor was it till 1806 that the New Connexion reached 6000.

During the period of quiet growth and development which followed 1797 the influence of one superior mind (Dr Jabez Bunting, 1779-1858) was to prevail with increasing sway. This was to be the period of the gradual development of lay co-operation in the administration of the various departments of Connexional extension and enterprise—a development which prepared the way for the important legislation of 1852 and following years, and for the ultimate settlement of the respective provinces and powers

[1] In this regulation it was assumed that the old rule of society by which a member disqualifies and virtually expels himself by continued absence from class, without reason for such absence, still held good. The case provides only for expulsions for "immorality." Subsequent legislation has introduced a provision which ensures to any member before he ceases to be recognized on account of non-attendance the right of having his case brought before a leaders' meeting if he desires it. This rule of 1797 has always been understood by the Conference as constituting the leaders' meeting in effect a jury, leaving the superintendent with his colleague or colleagues as advisers to act as judge. Appeal has always lain from the leaders' meeting to the district meeting, and, finally, to the Conference.

of the ministers and laity which was made in 1877–78. It was also to be the period of the gradual completion of the pastoral idea, in its practical application to the ministers of the body. This period may be defined as extending from the revolutionary epoch of 1791–97 to the epoch of political and municipal reform agitation, 1828–35, which coincides with a second period of politico-ecclesiastical agitation in Wesleyan Methodism.

In 1797 the *Conference*, as already *mentioned*, had refused to allow elected laymen—or lay delegates—any place either in the Conference or in district committees. Within a few years after 1800, however, the practice grew up for the circuit stewards to attend the district committees during the transaction of financial business, and in 1815 this usage was recognized in the Minutes of Conference as an established "rule," and it was enacted that no general increase of the income of the ministers should be sanctioned by the Conference until approved by a majority of the district committees during the attendance of the circuit stewards. Since the adoption of this rule the lay element in the district committees has steadily increased and developed. Another characteristic and important feature in the organization of Wesleyan Methodism, which grew into distinct form and prominence during the period now under review, was that of the administration of all the Connexional departments, except such as were regarded as properly pastoral, by means of mixed departmental committees, appointed at each successive Conference. These committees made recommendations to the Conference in regard to such new legislation as they thought desirable and to the appointment of the members of committee; and, for each department, a large committee of review, of which the members of the ordinary committee of management formed the nucleus, came to be held each year immediately before the Conference. In these committees the numbers of ministers and of laymen were equal. On this principle, between 1811 and 1835, provision had been made for the management of all the funds of the Connexion and their corresponding departments of administration. The first mixed committee appointed by the Conference was the committee of privileges in 1803.

The development of the pastoral position and character of the ministers of the body after 1797 could not but advance on a line parallel to the development of the position and claims of the laity. In 1818 the usage of the Conference was conformed to what had long been the ordinary unofficial custom, and the preachers began to be styled in the *Wesleyan Methodist Magazine* and in other official publications "Reverend," a fact which may seem trivial, but which in reality was of important significance.

In 1834, after the idea had been long entertained and the project had been repeatedly discussed, it was determined to establish a theological institution for the training of ministerial candidates. There are now four colleges, with two hundred and fifty students. In 1836 the practice of ordination by imposition of hands was adopted.

Such advances, however, as these in the general organization and development of the Connexion, and especially in the status and professional training of the ministers, could not be made in such a body without offence being given to some, whose tendencies were to disallow any official distinction between the ministry and the laity, and who also objected to the use of the organ. This levelling element was strong in the West Riding of Yorkshire, and in 1828, on the placing of an organ in Brunswick Chapel, Leeds, by the trustees, with the consent of the Conference, a violent agitation broke out. The consequence was a disruption, the first since 1798, under the title "Protestant Methodists." But this was absorbed, some years later, in a more considerable secession.

In fact, the Connexion was in 1828 entering on a period of agitation. The current of political affairs was approaching the rapids of which the Reform Act marked the centre and the point of maximum movement. A body like Wesleyan Methodism could not but feel in great force the sweep of this movement. It is true that Wesleyan Methodism as such has never been political, that few of its numbers cultivated extreme politics, and that the ministers and the better classes of the "Society" were strongly Conservative in their general tone. Nevertheless the mass of the community shared in the general movement of the times, and the Conservative tone of the ministers and of most of the well-to-do laity was not in full harmony with the sympathies of the people generally. Accordingly the elements of disturbance, which only partially exploded in the "Protestant Methodist" secession, continued to make themselves felt, in different parts of the Connexion, during the following years of political controversy. The decision of the Conference in 1834 to provide a college for the training of ministerial candidates gave special offence to the malcontents. Such an occasion was all that was wanting for the various discontents of the Connexion to gather to a head. The demands made by the agitators proceeded on a basis of democratic ecclesiasticism such as it is very difficult to apply successfully to a system of associated churches. The result was a third secession, based on the same general ground of ecclesiastical principles as the two preceding, which was organized in 1836, and with which the "Protestant Methodists" eventually coalesced. This new secession was known first as the "Wesleyan Methodist Association"; but for a number of years past it has been merged in a still larger body of seceders designated "The Methodist Free Churches." Its leader at the first was the Rev. Dr Warren, who left it, however, not many months after it was formed, and took orders in the Church of England.[1]

The controversies of 1835–36 left their mark on the legislation and official documents of the Connexion. The principles of 1797 remained intact, some further guards only being added to prevent any danger of hasty or irresponsible action on the part of superintendents, and at the same time "minor district meetings" being organized in order to facilitate appeals. One error was, however, committed by the Conference. In 1797 no provision had been made for bringing the circuit, through its quarterly meeting, into direct relations with the Conference. In 1836 a right of direct memorial to the Conference was given to the circuit quarterly meeting; but it was so fenced round with conditions and limitations as to make it practically inoperative, and at the same time provocative of suspicion and irritation.

The effect of the secession of 1836 on the general progress of the Connexion was not great. The number of members reported in 1835 in Great Britain and Ireland was 371,251 (there being a decrease in England of 951), in 1836 381,369, in 1837 384,723. For the next ten years the advance of the Connexion in numbers and in general prosperity was apparently unprecedented. The Centenary Fund of 1839–40 amounted to £221,000. In the midst, however, of all the outward prosperity of Methodism—partly perhaps in consequence of it—very perilous elements were at work. The revolutionary ideas of the Chartist period (1840–48) and of Continental politics (1848–49) reacted on Wesleyan Methodism as the political ideas of 1791 and of 1831 had done at those epochs. The embers of old controversies—ecclesiastical, quasi-political, and personal—still smouldered, and at length burst into fresh flame. From 1844 a strong spirit of opposition to the leaders of the Connexion, and especially to Dr Bunting, was fanned by the circulation of anonymous "fly leaves" of a very scurrilous character. At the same time the policy of the Conference and of the ministers in their circuits had proceeded more than was wise on the old lines. The general administration relied too much on the footing of implicit confidence on the part of the people and on the power of official prerogative in the hands of the minister. The memorial law of 1836 was indicative of the too exclusive spirit of pastoral government which had prevailed. The wisdom of Dr Bunting had for five and twenty years led the way in gradually liberalizing both the polity and the policy of Methodism, and adapting them to the changing conditions of the times. But this wisdom seems to have found its limits before 1849, when the internal dissensions reached their climax. In that year James Everett, the chief author of the fly sheets, and two other ministers, Samuel Dunn and William Griffith, who had identified themselves with him, were expelled. A disastrous agitation followed. No distinct secession took place till after the Conference of 1850. The union of the "Methodist Free Churches," in which was incorporated the "Wesleyan Association" (of 1836), was formed by the seceders. The "New Connexion" also received some thousands of the seceders into its ranks. But by far the greatest part of those who left went with neither of these bodies.

Between 1850 and 1855 the Connexion in Great Britain and Ireland lost 100,000 members, and not till 1856 did it begin to recover. In that year the numbers were returned as 282,787, showing a small increase over the preceding year. Since then peace and unity have prevailed unbroken.

The convulsion of 1849–52 taught the Connexion, and in particular the Conference, lessons of the highest importance. In 1852 the quarterly meeting was so defined as to make it the great representative meeting of the circuit, including stewards, leaders, local preachers, and trustees. The right of memorial to the Conference was given to it in the widest and freest sense. These powerful bodies invite ministers to the circuits, or decline so to do, determine and pay their "allowances," as salaries to ministers are still called in the Connexion, and review all the interests of the circuits, spiritual or financial. They had also conferred upon them in 1852 the right to appoint a circuit jury of appeal from the verdict and findings of a leaders' meeting in certain cases of discipline. Since 1852 Conference legislation has still proceeded in the direction of recognizing and enlarging the functions and rights of the laity. The committee of review system, already spoken of, had been considerably developed between 1835 and 1849, and included every department of ordinary administration. In 1861, however, whilst a representation of the departmental executive committees formed still the leading element in each committee of review, a great improvement was made in their constitution by giving to each of the districts of British Methodism the right to send a lay representative

[1] This "Warrenite" secession, as at first it was commonly called, gave rise to a lawsuit which led to the judicial recognition by the Court of Chancery of the Conference Deed Poll of 1784, and the "Large Minutes" of 1797, as documents having the force of public law in the administration of Wesleyan Methodism.

to attend these preparatory Conference committees. In 1877 and 1878 the final and natural consummation of the whole course of advance since 1791 was effected in the constitution of the united Conference of ministers and lay representatives. The ministers meet by themselves to discharge the functions which belong to them as the common pastorate of the Connexion. As to all the points involved in their specific character and common responsibility, as the mutually exchanging and itinerating pastors in common of a vast common flock, they take mutual counsel in a separate assembly. The Conference, in its ministerial-and-lay or representative session, meets after the pastoral business is completed, and occupies a full week between Sundays in discussing and settling the business of all the funds and the general administrative departments of the body. The Conference in its pastoral session assembles on the last Tuesday in July, that session closing on the Friday or Saturday week following; the representative session occupies the following week. It is legally necessary that the decisions of the Conference in both its sessions should be confirmed and validated by the vote of the "legal hundred." This confirmation is, however, given as a matter of course.

The Conference in its pastoral session is not formally representative. To each district is assigned by the preceding Conference a certain amount of representation, there being at present thirty-five districts. The numbers allocated to the districts vary according to circumstances. The total number of ministers and laymen composing the Conference in its representative session is 480, or 240 ministers and 240 laymen. The basis of the lay representation in the Conference is the constituency of lay officials in the district committees. The Connexion at large is represented by the lay officials of the general Connexional departments. The business transacted in the Conference during its representative session relates to all the Connexional departments of general administration, viz., the committee of privileges, foreign missions, the maintenance and education fund (and the schools) for ministers' children, chapel affairs (general, metropolitan, and provincial), the home mission and contingent fund, district sustentation funds, army and navy evangelization, lay mission work, the worn-out ministers' and ministers' widows' fund, the theological institution with its four colleges, Sunday and day schools and the children's home and orphanage, higher education, the extension fund of Methodism, alterations and divisions of circuits and districts, and the Lord's Day observance and temperance questions.

The president of the Conference is chosen by the ministers by ballot on the opening of the pastoral session. After the election of president follows that of secretary. These elections, however, cannot take place until the vacancies in the hundred have been filled up. Such vacancies are caused by death, by absence for two years together without a dispensation, by expulsion, or by superannuation, which takes place ordinarily after two years' retirement from the full work of the ministry.

The principal statistics of the denomination at the last Conference (1882) were as follows:—

	Members.	On Trial.	Ministers.	On Trial.	Retired or Supernumerary Ministers.	Sunday Scholars.
Great Britain	393,754	40,653	1,549	81	279	829,666
Ireland	24,475	776	200	18	43	
Foreign missions.[1]	89,363	12,934	343	198	16	

Of the Sunday scholars in Great Britain, 177,965 were over fifteen years of age, and 93,127 were members of society or on trial as members.

Wesleyan Methodism in Ireland has always been part and parcel of British Methodism, but since 1732 it has had a branch Conference of its own. The acts of this Conference are, in accordance with a provision in the Conference Deed Poll, made valid by the concurrence with them of a delegate from the British Conference, who is to the Irish Conference what the legal Conference is to the British Conference. Ten ministers of the Irish Conference are members of the "legal hundred" of the British Conference. The "plan of pacification" of 1795 was not carried out at the time by the Irish Conference. In the year 1816, however, it was adopted in Ireland. The result was a secession which assumed the designation "Primitive Wesleyans," a very different body from the Primitive Methodists of England. In 1878 the Primitive Wesleyans were reunited to the parent Connexion. The number of members in Ireland has, owing to emigration, not increased of late years. The last return showed 24,475 members.

Affiliated Conferences.—For more than twenty years there were several "affiliated Conferences" of British Methodism. But there are now only two—the *French Methodist* Conference, and that of *South Africa*,—the latter constituted quite recently (1882). Since 1852 French Methodism has been under an affiliated Conference. The dimensions of the French Connexion, however, are very small, and it is dependent to a considerable extent on pecuniary aid furnished by the Wesleyan Missionary Society. The last statistical return showed 1769 members, 126 members on trial, 27 ministers, 1 minister on trial, and 3 supernumerary or retired ministers. The British Conference has a right of veto as to certain points of legislation in the case of affiliated Conferences.

Australasian Methodism was for more than twenty years under an affiliated Conference, dating from 1854. Since 1876, however, the Australasian Conference has been independent. The General Conference meets once in three years, having under it our annual Conferences—one for New South Wales and Queensland, another for Victoria and Tasmania, a third for South Australia, and a fourth for New Zealand. These Conferences—the general and the annual—are all mixed and representative after the same general pattern as the British Conference. They have also under their charge, and as part of their Connexion, the Wesleyan missions in Tonga and Fiji, which were begun by the parent body before the original affiliated yearly Conference for Australasia was organized. The numbers in 1881 were for the Methodism of Australia 28,310 members with 362 ministers, and for the South Sea missions 33,411 members with 16 missionaries of European blood and a very large number of native ministers and assistant ministers.

Canadian Methodism was also affiliated till 1873, when it became an independent Connexion. It includes six provincial annual Conferences and one General Conference which meets every three years. The General Conference is mixed and representative; the annual Conferences are purely ministerial. Canadian Methodism occupies a powerful position in the Dominion. It numbers as nearly as can be ascertained about 116,000 members, and is strongest in Upper Canada. It possesses a university—the Victoria University in Upper Canada.

The Doctrines of Methodism.—In doctrine all branches of Methodism are substantially identical. Wesley's doctrines are contained in fifty-three sermons known as the "four volumes" and in his *Notes on the New Testament*. The Conference has, however, published two catechisms, one for younger the other for older children, of which a new and carefully revised edition has lately been completed.[2] In general, Wesleyan theology is to be described as a system of evangelical Arminianism. In particular, Wesleyan divines insist on the doctrines of original sin, general redemption, repentance, justification by faith, the witness of the Spirit, and Christian perfection,—or, as it has been customary for Methodists to say, the doctrines of a "present, free, and full salvation." By the witness of the Spirit is meant a consciousness of the Divine favour through the atonement of Jesus Christ. Wesleyans have often been represented as holding the Calvinistic doctrine of "assurance." The word, however, is not a Wesleyan phrase, and assurance, so far as it may be said to be taught by Methodists, signifies, not any certainty of final salvation, but merely a "sense of sin forgiven."[3]

II. American Episcopal Methodism.

The beginnings of American Methodism are traceable to the year 1766, when a few pious emigrants from Ireland introduced Methodism into New York. On receiving an appeal in 1768 from the New York Methodists, who were engaged in building a preaching-house, Wesley laid the case of America before the Conference at Leeds in 1769, and two preachers, Boardman and Pilmoor, volunteered to go to the colonies. Boardman went to New York, Pilmoor to Philadelphia. In 1771 two other Methodist itinerants, Francis Asbury—the most famous name in American Methodism—and Richard Wright, went out to America. In 1773 Thomas Rankin, a preacher of experience sent out

[1] Chiefly in the West Indies, Africa, India, and China.

[2] Besides Wesley's *Sermons* and *Notes*, his *Appeals* and his treatise on *Original Sin*, in reply to Dr Taylor of Norwich, should be read in order to appreciate his theological views. After these may be particularly noted Joseph Benson's *Commentary*, Watson's *Institutes* (3 vols.), Dr Pope's *Compendium of Theology* (3 vols.), the series of *Fernley Lectures*, especially that by the Rev. B. Gregory on "The Holy Catholic Church," and Dr Rigg's *Discourses and Addresses*.

[3] For the history and constitution of Wesleyan Methodism the following works may be consulted;—Wesley's Works, especially his *Journals*; Southey's *Wesley*; Tyerman's *Wesley*; Rigg's *Living Wesley*, and *Churchmanship of John Wesley*; Jackson's *Life of Charles Wesley*; *Minutes of Conference*, vol. i., 1744-98; Dr George Smith, *History of Wesleyan Methodism*, 3 vols.; Dr Abel Stevens, *History of Methodism*, 3 vols.; Pierce, *Polity of Methodism*; Dr Williams, *Constitution and Polity of Wesleyan Methodism*; Rigg, *Connexional Economy*; and the *Minutes*, 1877 to 1881.

by Wesley, held the first Conference in Philadelphia, when there were 10 itinerant preachers and 1160 members. After the breaking out of the War of Independence the English Methodist preachers were unpopular, and all but Francis Asbury went back to England. At the end of the war, however, in 1784, Wesley sent out Dr Coke, and American Methodism was organized as an independent church, with Dr Coke and Francis Asbury as its presbyter-bishops. The history of American Methodism since that period is too vast and complicated for any attempt to be made to summarize it here. Methodism is more properly national in its character as an American church than any church in the States. In Massachusetts and some other of the New England States it is less powerful than Congregationalism, which still retains there much of its ancient predominance; in the city of New York it is less powerful than Presbyterianism, and, indeed, occupies a position less generally influential than might have been expected. But in Philadelphia it is very powerful; so also in Baltimore and in Cincinnati; if not strong in New York city, it is very strong in the State; and generally throughout the western and mid-western States it is the prevalent form of faith and worship. In the south, also, it is more powerful than any other church.

American Methodism is Episcopal. But its Episcopacy is neither prelatical nor diocesan. The bishops are superintending presbyters, and they visit the whole territory of Methodism in rotation, holding (presiding over) the annual Conferences. These Conferences are purely ministerial. But the General Conference, which meets once in four years, and which is the Conference of legislation and final appeal, is mixed and representative. The first General Conference was held in 1792, the first delegated or representative Conference in 1812, the first mixed or ministerial-and-lay General Conference in 1872. There were till lately no district assemblies in the Episcopal Methodism of America, and now there are but few. The bishops maintain the unity of the Connexion in the interval between the General Conferences, by their visitation and by their conjoint council. A sub-episcopal class of ministers also, called presiding elders, supplement the action and superintendency of the bishops. These preside over districts, holding all the circuit quarterly meetings, and holding the district meetings, if any such meetings have been organized.

American Episcopal Methodism is distributed into five distinct sections or churches, which, however, differ from each other in no points of any importance as respects organization or discipline, still less doctrine. The American Methodist Episcopal Church South became a separate organization in 1847 by reason of the slavery controversy. The coloured churches, of which there are three, sprang up distinctly from local causes. The following are the latest available statistics:—

	Itinerant Ministers.	Local Preachers.	Lay Members.
Methodist Episcopal Church	12,142	12,323	1,717,567
" " " South	4,004	5,868	837,831
African " "	1,832	9,760	391,044
Methodist Episcopal Zion Church	1,650	3,750	300,000
Coloured Methodist Episcopal Church	638	683	112,000
	20,266	32,384	3,358,442

In the Methodist Episcopal Church alone there are one hundred annual Conferences, visited by twelve bishops. This church has more than twenty universities, of which some are distinguished schools of learning. Boston University is one of the most recent and one of the chief. The principal foreign missions are in India, China, and Japan. The Methodist Church South also has some influential universities, particularly that at Nashville, and has missions, in particular in Japan and China.

Besides these Methodist Episcopal churches, with their total of 3,358,000 church members, there are two other churches which do not assume the name at all, but are yet essentially Methodist in doctrine and discipline, not varying in any important particulars from the Episcopal Methodism of America. Of these one is called the United Brethren, with 157,000 members, the other the Evangelical Association, with 113,000 members.[1]

Non-Episcopal American Methodism.—The bodies included under this head are chiefly secessions from the original stock of American Methodism, founded on principles of democratic church government, analogous to those of the English Methodist secessions. The only considerable body, however, is the Methodist Protestant Church, with 125,000 members. The minor bodies, four in number, count altogether less than 60,000 members, the principal being the American Wesleyan Church, with 25,000 members.

III. Other Methodist Bodies in Britain.

The bodies still to be noticed, while differing as to points of church government, agree as to doctrine and in general as to the means of grace and as to inner spiritual fellowship with the parent "Connexion." They all maintain class-meetings and love-feasts, have leaders' meetings and quarterly meetings, and largely employ local preachers.

The Methodist New Connexion was founded in 1797–98 by Alexander Kilham, who died in 1798. Its general principles are indicated above. Its statistics for 1881 were as follows:—183 ministers and 27,770 members (including those on mission stations, besides 3882 on trial), and 74,744 Sunday scholars.[2]

United Methodist Free Churches.—This organization in its original form must be identified with the Wesleyan Methodist Association of 1836. That body first absorbed into itself, in great part, the "Protestant Methodists" of 1828. It was afterwards greatly increased, and its organization in some points modified, when a large number of the seceders from the parent Connexion in 1850–52 joined its ranks. The main body of its Conference does not consist, like that of the New Connexion, of an equal number of circuit ministers and elected circuit lay delegates, but of circuit delegates, whether ministerial or lay, elected without any respect to office, ministerial or other. Its circuits also are independent of the control of the Conference. The Connexional bond, accordingly, in this denomination is weak, and the itinerancy is not universal or uniform in its rules or its operation. The amalgamation between the Wesleyan Methodist Association and the "Wesleyan Methodist Reformers" of 1850 took place in 1857. At that time the combined churches numbered 41,000. At present (1881–82) they number 72,839, including 7772 members on the mission stations, besides 7824 on trial. The number of ministers is 392, with 40 retired or "supernumerary" ministers. The number of Sunday scholars is 190,957.[3]

Primitive Methodism.—In this earnest and hard-working denomination the ministers, of whom some are women, are very literally "the servants of all." The Conference is composed, in addition to twelve permanent members, of four members appointed by the preceding Conference, and of delegates from district meetings. The principle of proportion is that there should be two laymen to one minister or "travelling preacher," and the "travelling preachers" have no pastoral prerogative whatever. The Conference is supreme, and the Connexional bond is strong. This body was founded by Hugh Bourne and William Clowes, local preachers who were separated from the Wesleyan Connexion, the former in 1808, the latter in 1810, because of their violation of Conference regulations as to camp meetings and other questions of order. The Conference had, in 1807, pronounced its judgment against camp meetings, which had been introduced into the country from America, whereas Bourne and Clowes were determined to hold such meetings. Founded thus by zealous and "irregular" lay preachers, "Primitive" Methodism, as the resulting new body called itself, bears still in its organization, its spirit, and its customs strong traces of its origin. It has been a very successful body, aiming simply at doing evangelistic work, and is now numerous and powerful, numbering among its ministers, not only many useful preachers, but some of marked originality and power and also of superior cultivation. There has for many years past, if not from the beginning, been a very friendly feeling between the old Wesleyan Connexion and the Primitive Methodists. Its latest statistics (1881–2) show 1149 travelling preachers, 185,312 members, and 383,350 Sunday scholars.[4]

Bible Christians.—The Primitive Methodists sprang up in the midland counties, the Bible Christians in Cornwall. These closely resemble the "Primitives" in their character and spirit. Their founder was a Cornish local preacher called O'Bryan. Hence the Connexion is often known as the Bryanites, and Cornish emigrants have propagated this denomination widely in the colonies. The Conference is composed of ten superintendents of districts, the president and secretary of the preceding Conference, lay delegates, one from each district meeting, and as many of the travelling preachers as are allowed by their respective district meetings to attend. In general it may be said that the ministerial and lay members of the Conference are about equal in number. The returns for 1881–82 showed in England (chiefly the west and south of Eng-

[1] The best authority as to American Methodism is Dr Abel Stevens's *History*, in 5 vols. The statistics are given in the *Methodist Year Book*, New York, 1882.

[2] See *Jubilee Volume of the New Connexion*; also the *General Rules* and the *Minutes of Conference*, 1881, published at the New Connexion Book-Room.

[3] See *Foundation Deed of the United Methodist Free Churches*; also *Minutes of Conference*, 1881, 119 Salisbury Square.

[4] See John Petty, *History of the Primitive Methodist Connexion*; also *Minutes of Conference*, 1881, 6 Sutton Street, London, E.

land) and in the Channel Islands 136 itinerant preachers, 21,209 members (besides 690 on trial), and 36,335 Sunday scholars. In Canada the number of members was 6652, and in Australia and New Zealand 3671.[1]

The Wesleyan Reform Union is an aggregate of local Methodist secession churches, loosely held together by a Conference, and is one of the results of the great Methodist disruption of 1851-52. The returns for 1881-82 showed 18 ministers and 7728 members.

Œcumenical Methodist Conference.—This Conference was held in City Road Chapel, London, in September 1881. Representatives were present from all the Methodist bodies throughout the world, and it was estimated that these represented not less than 5,000,000 of members and 20,000,000 of population. Whilst in church organization these bodies differed, as has been shown above, in doctrine and in respect of their purely spiritual discipline and means of grace, they were all agreed in principal matters. The Conference was entirely practical in character. The object was to promote zeal and union among the constituent bodies as to all practical points of Christian sympathy and activity, at home and abroad, and especially as to home mission work, general philanthropy, Christian education, and a Christian use of the press. There were 100 representatives present from the Methodist bodies in all parts of the world.[2]

Welsh Calvinistic Methodists.—Between the Methodism of Wales and that of England there was never any other than incidental connexion. Indeed, although the name of the Welsh movement was borrowed from the English, not only was Welsh Methodism quite independent in its origin, but in reality its beginning, as an evangelical movement, was earlier than that of English Methodism. From Wesleyan Methodism, furthermore, Welsh Methodism was throughout distinguished by the fact that it was Calvinistic in its doctrine. For some years Whitefield's name was placed by the leaders of Welsh Methodism at the head of their movement, but the connexion was not at any time much more than nominal, Whitefield being, indeed, too often and too long together in America to exercise any real presidency over the Methodism of the Principality.

Distinction, however, must be made between Welsh Methodism as an evangelistic movement and as an organization. In its later and distinctly organized form, its main elements date from 1811, while the actual unity and the final consolidation of the organization date from so recent a period as 1864. At that date we find the Calvinistic Methodism of North and of South Wales for the first time united in a common organization and government, and brought under the supreme control of one "General Assembly."

The spiritual awakening from which Welsh Calvinistic Methodism derived its earliest inspiration and impulse began in 1735 and 1736, almost contemporaneously and quite independently, in three different counties of South Wales. Howell Harris, a gentleman of some position, born and bred at Trevecca in the parish of Talgarth, county of Brecon, is the most prominent name connected with early Welsh Methodism. His first strong religious convictions and impulses date from 1735. He was sent to Oxford in the autumn of that year to "cure him of his fanaticism," but remained only one term. On his return to Wales he began to exhort and preach in private houses and in such buildings as he could obtain the use of, being then and throughout his life a simple layman. Of learning or theology he had but little; but he was an extemporary preacher of prodigious vehemence, and often of overwhelming power and pathos. While Harris was thus preaching in the county of Brecon, Daniel Rowlands had been spiritually awakened at Llangeitho in Cardiganshire, the two men knowing nothing whatever of each other. Rowlands was an ordained clergyman, of some learning and of great eloquence. He was a pulpit orator, and carefully prepared his powerful discourses. In Pembrokeshire, again, in that same year 1735-36, Howell Davies began to preach the same doctrine in the same spirit as the other two preachers, and with effects scarcely, if at all, less remarkable. The work thus begun in three distinct centres within the space of one year was in strict connexion with the Established Church, and so continued to be throughout the last century. These single-minded preachers pursued their work in Wales knowing nothing of the parallel work which Whitefield had just begun in England. In 1738, however, Whitefield, in the west of England, heard of Howell Harris, and in that year the two revivalists met in Cardiff. In 1739 Howell Harris had begun to extend his preaching tours far and wide, visiting not only South but North Wales, and, wherever he went, founding religious societies in connexion with the Church of England, of a character resembling those called Dr Woodward's societies, which had long been in existence throughout England, the chief difference being that the Welsh societies were "evangelical," Calvinistic, and revivalist. It was in the same year that Wesley founded his society in England. In 1742 the clergymen connected with the Welsh movement were ten in number, and there were labouring in concert with these forty lay "exhorters," as they were called. In that year the first "association" of Welsh Calvinistic Methodists was held at Waterford or Watford, in Glamorganshire. Whitefield consented to preside, and joined his preaching to that of the Welsh evangelists. The first Calvinistic Methodist Conference was held at Waterford, under Whitefield's presidency, on January 5, 1743, eighteen months earlier than Wesley's first Conference. For a short time the Calvinistic Methodism of Wales was linked to that of England. After 1748, however, Whitefield ceased to act as in any sense the official head of the Calvinistic Methodists of England, and their organization, always loose, was gradually dissolved.

There was no Wesley in Welsh Methodism, and accordingly there was no organic unity among the societies of earlier Welsh Methodism. Each local society was under the care of an "exhorter," an unpaid layman. A number of these local societies were grouped together into a district, over which an "overseer" had charge. He also was usually an unpaid layman, although exercising many of the functions of a spiritual pastor. Sometimes, however, as in the case of Rowlands, he was a parish clergyman. The societies attended their parish churches and there received the sacraments. The meeting- or preaching-houses for the societies were vaguely called "houses for religious purposes."

In 1751 Howell Harris ceased to itinerate and retired to Trevecca. From this time his leadership in the Methodist movement seems to have come to an end, and the movement languished for many years after. Not till 1762 is any "revival" chronicled. In 1763 Rowlands was obliged to quit his curacy at Llangeitho and leave the Established Church. His people built him a chapel. He thus, after 1763, became a Dissenting minister; and, retaining his fame and much of his power to the end of his course, he died in 1790.

Fifty years had now passed since the first societies of Welsh Methodism had been established by Howell Harris, and the movement, instead of having grown to strength and maturity, appeared to have spent its force, almost in all directions, at least so far as any outward signs could show. But the Rev. Thomas Charles of Bala was to be one of the chief means of reviving it. He, like the earlier Methodists, was a churchman; he had taken his degree at Oxford and served a curacy in Somersetshire. The doors of the Established Church having been closed against him because of his style of preaching, he joined the Welsh Methodists in 1785, and his first sphere of marked influence was in North Wales. In 1791 he took a leading part in a great revival of which Bala was the centre. From this period may be dated the second spring of Welsh Calvinistic Methodism, from which its later successes were to grow. Charles zealously and successfully promoted the establishment of "circulating schools" and of Sabbath schools. He was, in fact, the soul of the great Christian educating movement in Wales which began in the last decade of the 18th century; and it was through his earnest zeal in seeking to provide Bibles for his Welsh schools, especially the Sunday schools, that the British and Foreign Bible Society was established. Though Methodism came then to be effectually rooted in the soil of the Principality, it was not till 1811 that the Welsh Calvinists took that step in the direction of ecclesiastical independence which the English Wesleyans had taken sixteen years before by calling their preachers to the official position of pastors and ordaining them to administer the sacraments.

From 1790 till almost the present time the work of gradually moulding the constitution of Welsh Calvinistic Methodism has proceeded. The "rules regarding the proper mode of conducting the quarterly association" were drawn up by Charles and agreed upon in 1790. In 1801 the *Order and Form of Church Government and Rules of Discipline* were published. In 1811, as has been shown, ministerial ordination was initiated. In 1823 the *Confession of Faith* was promulgated. And in 1864, as has been already mentioned, the first "General Assembly" was held, and the two associations of North and South Wales respectively were united into one body. The constitution is now a modified Presbyterianism, each church managing its own affairs subject to successive appeal to the monthly meeting of the county and the quarterly association of the province, while the latter body may refer the decision to the annual General Assembly.

The Welsh Methodists (or Welsh Presbyterians, as they are now often called) have two theological colleges, one at Bala and the other at Trevecca. They have also a foreign missionary society, with missions in Brittany, among their congeners of the Celtic race, and in Bengal.

In recent years this church has made great progress. In 1850 the number of members was 58,678, in 1870 it was 92,735, and in 1880 the returns showed 1174 churches, 118,979 communicants, 185,635 Sunday scholars. The number of ministers is not officially given, but is estimated at 600. The North and South Wales associations are now also known as synods.[3] (J. H. RI.)

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[1] See *Bible Christian Memorial Volume*, 1866; *Minutes of Conference*, 1881, Book-Room, 26 Paternoster Row.

[2] See *Proceedings of First Methodist Œcumenical Conference*, Wesleyan Book-Room, City Road.

[3] See W. Williams, *Welsh Calvinistic Methodism, a Historical Sketch*; *The Life and Times of Howell Harris*; Tyerman, *Life of the Rev. George Whitefield*; *The Diary of the Calvinistic Methodists*. 1882.

is never made synthetically, but simply extracted from wood-spirit, a commercial substance which is produced industrially in the dry distillation of wood. The wood-spirit is contained in the aqueous portion of the tar produced in this operation, along with acetic acid. To recover both, the tar-water is neutralized with lime and distilled, when the acetate remains, while the spirit distils over, along with a deal of water, which, however, is easily removed, as far as necessary, by redistillation and rejection of the less volatile parts. The "crude" wood-spirit, as thus obtained, is not unlike in its general properties to ordinary spirit of wine, from which, however, it is easily distinguished by its abominable smell. The ordinary commercial article, besides a variable percentage of water, contains from 35 to 80 per cent. of methyl-alcohol; the rest consists chiefly of acetone, but besides includes dimethyl-acetal, $C_2H_4(OCH_3)_2$, acetate of methyl, and numerous other minor components. In Great Britain large quantities of wood-spirit are used for the making of methylated spirit, a mixture of ordinary spirit of wine with one-ninth of its volume of wood-spirit, which is allowed to be sold duty free for the preparation of varnishes, and for other industrial purposes. In former times, here as elsewhere, wood-spirit itself used to be employed as a cheap substitute for spiritus vini; but this is no longer so, since the aniline-colour industry has created a large demand for pure methyl-alcohol. Hence in some Continental works the wood-spirit, instead of being sent out as such, is being worked up for its components, by the following sequence of operations:—(1) dehydration by lime; (2) heating, under an inverted condenser, with caustic soda, to convert the acetate into hydrate of methyl; (3) destruction of the bad smells by mild oxidation; (4) distillation in a kind of Coffey's still, whereby it is split up into approximately pure alcohol, acetone, and "tails."

The new industry led to the invention of the following technical methods for the determination, in a given spirit, of the percentages of real methyl-alcohol and of acetone.

The alcohol is determined by saturating 5 c.c. of the spirit with hydriodic acid (volatilization of alcohol and iodide of methyl being avoided by means of a cold-water bath and an inverted condenser), and the product poured into water. Iodide of methyl separates out as a heavy oil, which is measured as it is. According to direct trials 5 c.c. of pure methyl-alcohol yields 7·15 c.c. of crude iodide (Krell, Kramer and Grodzky).

For the determination of the acetone the following reagents are required (Kramer):—(1) a solution of iodine, prepared by dissolving $I_2 = 254$ grammes of iodine, by means of (say) 500 grammes of iodide of potassium, in water, and diluting to 1 litre; (2) a solution of caustic soda containing twice (NaOH) grammes per litre; (3) alcohol-free ether. Ten c.c. of the soda are placed in a graduated cylinder and mixed intimately, first with 1 c.c. of the spirit, then with 5 c.c. of the iodine solution. Iodoform separates out (if acetone is present) in minute yellow crystal plates; this product is "shaken out" by means of 10 c.c. of ether, and determined by evaporating an aliquot part of the ethereal layer in a tared watch-glass to dryness and weighing the residue. C_3H_6O yields CHI_3; hence 1 part of iodoform indicates 0·28 parts of acetone.

The formula of methyl-alcohol and its true chemical character were correctly ascertained by Dumas and Péligot as early as 1834; yet pure methyl-alcohol may be said to have been an unknown substance until 1852, when Wöhler taught us to prepare it, by first extracting the CH_3 of the CH_3OH in the wood-spirit as oxalate of methyl, and then decomposing the (purified) oxalate with water.

The most convenient raw material to use nowadays is the commercial "pure" alcohol; if wood-spirit is employed it had better first be purified by distillation over caustic soda (vide supra). The formation of the oxalate then is best effected (according to Alexander Watt) as follows:—500 grammes of oxalic acid crystals are mixed with 200 c.c. of oil of vitriol; then 500 c.c. of the spirit are added, the whole kept for a time at 80° C., and then allowed to stand cold for twenty-four hours.

The large crop of oxalate crystals—partly $(CH_3)_2C_2O_4$, partly $CH_3 . H . C_2O_4$—is separated from the liquor by pressure and subsequent drying over vitriol, and then decomposed by distillation with water.

The aqueous alcohol thus obtained is dehydrated by the well-known methods used in the preparation of ordinary absolute alcohol.

According to Krämer, a purer preparation than Wöhler's is obtained by extracting the methyl as formiate instead of as oxalate, which is easily effected by digesting the wood-spirit with a formic acid of 1·22 specific gravity, and purifying the formic ether by fractional distillation. This ether boils at 32°, the oxalate at 161° C., hence a proper combination of the two methods should be infinitely superior to either. What now follows must, in general, be understood to refer to Wöhler's preparation.

Pure methyl-alcohol is a colourless liquid similar in its general properties, in its behaviour to other chemically inert liquids, and in its action as a solvent to ordinary absolute alcohol, from which, however, it differs by the entire absence from it of all spirituous odour. A preparation which smells of wood-spirit may be condemned at once as impure. According to H. Kopp, its specific gravity is 0·8142 at 0° C. and 0·7997 at 16°·4. If the volume at $t°$ be V, then (from 0° to 61°)

$$V = 1 + \cdot 0011342t + 1\cdot 3635 \times 10^{-6}t^2 + 8\cdot 741 \times 10^{-9}t^3.$$

The boiling point is 64°·6 to 65°·2. The tension-curve was determined by Regnault and by Landolt; but the results of the two observers do not agree except (approximately) at $P = 760$ mm. Methyl-alcohol has quite a characteristic tendency to "bump" badly on distillation, which, however, can be prevented by addition of a small fragment of tin-sodium, which produces a feeble but sufficient current of hydrogen. Its specific heat is ·6713; latent heat of vapour, 264; combustion heat, 5307 per unit weight (Favre and Silbermann). The refractive index for the D (sodium) ray is 1·3379 ± ·0013 for 10° ∓ 5° C. (Dale and Gladstone).

Methyl-alcohol mixes with water in all proportions with contraction.

Since Wöhler's discovery a table for the specific gravities of aqueous methyl-alcohols has been constructed experimentally by A. Dupré; but unfortunately his alcohol boiled at 58°·7, and consequently must have been something different from what generally goes by this name.

In its chemical reactions methyl-alcohol, $CH_3 . OH$, is very similar to ordinary (ethyl) alcohol, $C_2H_5 . OH$, and consequently, in the same sense as the latter, analogous to water, $H . OH$. Thus, for instance, metallic sodium and potassium dissolve in either alcohol with evolution of hydrogen and formation of ethylates or methylates of the alkali metals. Example—

$$CH_3OH + Na = CH_3 . ONa + \tfrac{1}{2}H_2.$$

The two methylates crystallize from the solution with crystal-alcohol, which can be driven off in an atmosphere of hydrogen by heat, without decomposition of the salts themselves. Water at once decomposes them into caustic alkali and alcohol, $CH_3 . ONa + H . OH = NaOH + CH_3OH$. Yet the reverse reaction takes place when the alcohol is treated with a large excess of caustic soda.

The action of acids on methyl-alcohol is in general quite analogous to that on, for instance, caustic soda, with this important difference, however, that what in the case of NaHO goes on so readily in aqueous solutions with $CH_3 . OH$ succeeds only under circumstances precluding the accumulation of water. In these circumstances we have, for instance,

$$(1)\ Cl\overline{H + OH} . CH_3 = H_2O + Cl . CH_3;$$

$$(2)\ \underset{\text{Acetic acid.}}{(C_2H_3O_2)}\overline{H + OH} . CH_3 = H_2O + \underset{\text{Acetic ether}}{C_2H_3O_2 . CH_3};$$

and so on with all monobasic acids. A dibasic acid XHH may act as $(X)H_2$ or as $(XH) . H$; thus, for instance,

$$(3)\ \underset{\text{Oxalic acid.}}{(C_2O_4H)}\overline{H + OH} . CH_3 = H_2O + \underset{\text{Methyl oxalic acid.}}{C_2O_4 . HCH_3};$$

$$(4)\ (C_2O_4)H_2 + 2OH . CH_3 = 2H_2O + \underset{\text{Methyl oxalate.}}{C_2O_4 . (CH_3)_2};$$

A tribasic acid forms two methyl acids and one neutral ether; we have, for instance,

(5) (From PO_4H_3); $PO_4(CH_3)H_2$; $PO_4(CH_3)_2H$; $PO_4(CH_3)_3$.

It would, however, be a great mistake to suppose that whether, for instance (Ex. 3 and 4), the monomethyl or the dimethyl compound is formed depends on the quantity of methyl-alcohol employed per unit of acid. This depends far more largely on other conditions, as will be illustrated in next paragraph. The methyl-salts of oxygen acids are called esters, in opposition to the chloride, bromide, iodide, sulphide, and oxide, which are set apart as ethers. Broadly speaking, ethers are not, while esters are, readily decomposed by water into their cogeners; but the nitrate $CH_3 . NO_3$ behaves in this respect like an ether.

Action with Sulphuric Acid.—Methyl-alcohol mixes with oil of vitriol with considerable evolution of heat and (always only partial) conversion of the two ingredients into methyl-sulphuric acid. Equal volumes of acid and alcohol give a good yield. To prepare pure methyl sulphates, dilute the mixture largely with water, avoiding elevation of temperature (which would regenerate the ingredients), and saturate with carbonate of baryta. Filter off the sulphate of baryta to obtain a solution of the pure methyl sulphate $SO_4 . CH_3 . ba$ (where $ba = \frac{1}{2}Ba = 1$ *eq.*), from which this salt is easily obtained in crystals. From the baryta salt any other methyl sulphate is readily obtained by double decomposition with a solution of the respective sulphate; the acid itself, for instance, by means of sulphuric acid. At higher temperatures the reaction between vitriol and methyl-alcohol results in the formation of methyl-ether, $(CH_3)_2O$, or of normal sulphate of methyl, $(CH_3)_2SO_4$. The ether is a gas condensable into a liquid which, under pressure of one atmosphere, boils at $-21°$ C.

The gas dissolves in about one thirty-seventh of its volume of water; far more largely in alcohol and in ether; most abundantly in oil of vitriol, which dissolves about six hundred times its volume of methyl-ether gas, thus affording a very handy means for storing up the gas for use. The solution needs only be diluted with its own volume of water to be broken up into its components (Erlenmeyer).

Liquefied oxide of methyl is now being produced on the manufacturing scale, and sold as a powerful refrigerating agent. One part of sulphuric acid is mixed with a little over one part of dehydrated wood-spirit, and the mixture heated to 125° to 128° C. (130° being carefully avoided), when methyl-ether goes off. When the mixture is exhausted, more wood-spirit is added to the residue so as to re-establish the original specific gravity (of 1·29), and the heating resumed, which again furnishes a supply of the gas, and so on. This proves that the process is not, as used to be supposed, one of mere dehydration, but a cycle of reactions analogous to those in the ordinary process of etherification, as shown by the equations:—

(1) $SO_4H_2 + CH_3OH = SO_4 . HCH_3 + H_2O$.

(2) $SO_4 . H . CH_3 + H . O . CH_3 = SO_4HH + CH_3 . O . CH_3$.

The ester, $SO_4(CH_3)$, though obtainable by distillation of the alcohol with 10 parts of vitriol, is more conveniently prepared from pure methyl-sulphuric acid by distillation in vacuum at 130°–140° C; thus:—$2SO_4CH_3 . H = SO_4H_2 + SO_4(CH_3)_2$. It is a colourless liquid, smelling like peppermint, specific gravity 1·327 at 18°; it boils at 187° to 188° C.

Chloride of methyl, CH_3Cl, readily produced by the action of hydrochloric acid gas and hot methyl-alcohol (preferably in the presence of chloride of zinc as an auxiliary dehydrator), is a gas which, under ordinary pressure, condenses into a liquid at $-23°$ C. The gas, at ordinary temperatures (though very readily soluble in alcohol), is only sparingly absorbed by water, which, however, at 6° unites with it into a solid hydrate. Condensed methyl chloride has become an article of commerce, being largely produced from trimethylamine (*vide infra*) and used as a powerful frigorific agent, as well as for the extraction of perfumes from flowers. Regarding nitrite of methyl, $NO—O—CH_3$, its interesting isomeride nitromethane, $O_2N—CH_3$, and nitrate of methyl, NO_3CH_3, we must refer to the handbooks of organic chemistry.

Iodide of methyl, CH_3, is obtained by distilling methyl-alcohol with hydriodic acid, which latter is best produced off-hand by addition to the alcohol of iodine and amorphous phosphorus. It is a colourless liquid of 2·269 specific gravity, boiling at 42°·5 C., insoluble in water.

Organic Methyl-Esters.—The more volatile ones are in general easily obtained by distillation of the respective acid with methyl-alcohol, or with methyl-alcohol and oil of vitriol (virtually $SO_4 . H . CH_3$); the less volatile ones more conveniently by passing hydrochloric acid gas into a methyl-alcoholic solution of the acid. We have no space for the individual substances; but the salicylate $C_7H_5O_3 . CH_3$ may just be named as being the principal component of the essential oil of *Gaultheria procumbens* (wintergreen oil).

Methylamines.—The general result of the action of ammonia on an ester is the formation of alcohol and acid amide. Example—

$$\underbrace{(C_2H_3O)-\overline{O-CH_3}}_{\text{Acetate of methyl.}} + HNH_2 = CH_3 . OH + \underbrace{C_2H_3O . NH_2}_{\text{Acetamide.}}.$$

With iodide of methyl this reaction is an obvious impossibility; what really takes place (as A. W. Hofmann has shown for this and all analogous cases) is that the iodide unites with the ammonia into the HI compound $HI . NH_2CH_3$ of a base NH_2CH_3, which can be separated from the acid by distillation with caustic potash, and when thus liberated presents itself as a gas surprisingly similar (almost to identity) to ammonia. The analogy extends to the action on iodide of methyl, which, in the case of methylamine, NH_2CH_3, leads to the formation of dimethylamine, $NH . (CH_3)_2$; and from the latter again trimethylamine, $N(CH_3)_3$, can be prepared by a simple repetition of the operation. These three amines are closely analogous in their chemical character to ammonia, the points of difference becoming the more marked the greater the number of (CH_3)'s in the molecule. Trimethylamine, having lost all its ammonia-hydrogen, cannot possibly act upon iodide of methyl like its analogues. What it really does is to unite with the iodide into "iodide of tetramethyl-ammonium," $I . N(CH_3)_4$, analogous to iodide of ammonium, INH_4, we should say, if it were not the reverse, because the organic iodide (unlike its prototype, which is an ammonium compound only in theory), when treated with moist oxide of silver (virtually with AgOH), really does yield a solution of a true analogue of caustic potash in the shape of hydroxide of tetramethyl-ammonium, $N(CH_3)_4 . OH$.

In regard to the actual preparation of these several bodies, which is not so simple as might appear from our exposition of their mutual relations, we must refer to the handbooks of organic chemistry. But we must not omit to state that trimethylamine, which only the other day was never seen outside a chemical museum, is now being manufactured on a large scale, and promises to play an important part in industrial chemistry. The waste liquors obtained in the distillation of alcohol from fermented beet-root molasses serve as a raw material for its preparation. These liquors, when evaporated to dryness and subjected to dry distillation, yield, besides tar and gases, an aqueous liquid containing large quantities of ammonia, acetonitrile, methyl-alcohol, and trimethylamine. This liquor is neutralized with sulphuric acid, and distilled, when the nitrile and the methyl-alcohol distil over, to be recovered by proper methods. From the mixed solution of the sulphates of ammonia and trimethylamine the former is separated out as far as possible by crystallization; the mother-liquor

is distilled with lime; the volatile bases are absorbed in hydrochloric acid; the hydrochloric solution is evaporated; and the sal-ammoniac which comes out at first is, as far as possible, fished out. The last mother-liquor is evaporated to dryness, and in this form represents commercial trimethylamine hydrochlorate. It is this product which serves for the preparation of methyl chloride (*vide supra*), the process being founded upon the fact that a concentrated solution of the salt, when heated, breaks up $3HCl \,.\, N(CH_3)_3$ into $2N(CH_3)_3$ of free trimethylamine + $NH_2 \,.\, CH_3HCl$ of hydrochlorate of monomethylamine and $2CH_3Cl$ of methyl chloride.

These processes are being carried out industrially by Vincent in France. But this base trimethylamine seems destined to do more than provide us with a new refrigerating agent. The attempt has been made—it would appear, with success—to utilize it for the preparation of pure carbonate of potash from native chloride of potassium, just as ordinary ammonia, in the famous ammonia-soda process, serves for the conversion of common salt into soda-ash.

Methyl Cyanides.—There are two distinct bodies which, by composition and by synthesis, are both $CH_3 + NC$; they are named "acetonitrile" (formerly called simply cyanide of methyl) and isocyanide of methyl or methylcarbamine respectively.

Acetonitrile was discovered by Dumas in 1847. It may be prepared by the distillation of a mixture of methylsulphate and of cyanide of potassium; but is obtained more easily and in a purer state by distilling acetamide with phosphoric anhydride. Acetate of ammonia may be used instead of the amide, but it does not work so well.

$CH_3 \,.\, CO \,.\, O(NH_4)$	$CH_3 \,.\, CO \,.\, (NH_2)$	$CH_3 \,.\, CN$
Acetate of NH_3	Acetamide	Nitrile
$= A$ (say).	$= A - H_2O$.	$= A - 2H_2O$.

It is a colourless liquid of a pungent aromatic odour, with specific gravity ·805 at 0°, and boils at 82° C. When heated with aqueous potash (at the wrong end of a condenser) it breaks up with formation of ammonia and acetate of potash. Whence we conclude that the methyl is combined more directly with the carbon of the cyanogen, thus:

$$N\{\overline{C—CH_3}\} + 2H_2O = NH_3 + \underset{\text{Acetic acid.}}{CH_3 \,.\, COOH} \,.$$

This conclusion is supported by the action on the nitrile of nascent hydrogen, which leads to the formation of ethylamine, thus (Mendius):—

$$NC—CH_3 + 4H = \underset{\text{Ethylamine.}}{H_2N—CH_2CH_3} \,.$$

In either case we pass from a monocarbon to a dicarbon body, virtually from methyl to ethyl alcohol.

The isocyanide is prepared by heating iodide of methyl with cyanide of silver (CH_3I; $2NCAg$) and ether in a sealed-up tube to 130° to 140°, to produce the crystalline body $AgNC + NCCH_3$ (and AgI). The double cyanide, when distilled with some water and cyanide of potassium, breaks up into its components,—the $NCAg$ forming $(NC)_2AgK$; and the cyanide of methyl distils over. It is a colourless liquid, characterized by quite an unbearably irritating and sickening smell. The specific gravity is ·756 at 14°, the boiling point 59° C. It combines with hydrochloric acid into a crystalline salt which is readily decomposed by water into methylamine and formic acid. Whence we conclude that in this case the cyanogen is tied to the methyl by its nitrogen; thus:—

$$C\{N—CH_3\} + 2H_2O = \underset{\text{Formic acid.}}{H \,.\, COOH} + \underset{\text{Methylamine.}}{NH_2 \,.\, CH_3} \,.$$

The methyl here remains methyl, being separated by an N from the cyanogen-carbon, which latter passes into formic acid.

We must not close this section without at least referring to the *methylphosphines*, as being a set of bodies related to PH_3 (phosphine) as the methylamines are to NH_3 (ammonia), and similar to these in their chemical character, in so far as they are bases. The points of difference between the two series are of pretty much the same sense as those between the two prototypes. Thus, for instance, while trimethylamine $N(CH_3)_3$ is a strong base, but inert to oxygen gas, trimethylphosphine is a relatively feeble base, but in contact with air greedily absorbs oxygen with formation of an oxide $P(CH_3)_3O$, the like of which in the nitrogen series has no existence.

Sulphur Compounds of Methyl.—Substances analogous to methyl-alcohol and methyl-ether respectively can be obtained by the distillation of methyl sulphate of potassium with strong solutions of the potassium sulphides KHS and K_2S respectively. The body $CH_3 \,.\, SH$ is known as methyl-mercaptane, the other $(CH_3)_2S$ as sulphide of methyl. Both are very volatile stinking liquids. Sulphide of methyl claims a special interest as being the starting point for the preparation of an important class of bodies called trymethyl sulphine compounds. The sulphide $(CH_3)_2S$ readily unites with the iodide CH_3I into crystals of iodide of trimethyl sulphine, $(CH_3)_3S \,.\, I$, a substance which is closely analogous in its chemical character to the iodide of tetramethyl-ammonium. Moist oxide of silver, for instance, converts it into a strongly basic hydrate, $S(CH_3)_3 \,.\, OH$, which in its avidity for acids almost beats its analogon in the nitrogen family. An investigation of its salts was published by Crum Brown and Blaikie.

Methyl Arsenides.—Arseniferous bases constituted like mono- or di-methylamine (bodies such as AsH_2CH_3, analogous to $NH_2 \,.\, CH_3$) do not seem to exist. What we do know of are—(1) a trimethylarsine and the iodide and the hydroxide of tetramethylarsonium, —$As(CH_3)_3$, $As(CH_3)_4I$, and $As(CH_3)_4OH$,—bodies discovered by Cahours and Riche; (2) a whole series of monomethylic bodies, $As(CH_3)X_2$ (where $X = Cl$, Br, or $X_2 = O, S$), discovered by Baeyer in 1857; (3) the kakodyle compounds, a series of bodies, $As(CH_3)_2 \,.\, X$ or $As(CH_3)_2 \,.\, X_3$, which were discovered and investigated by R. Bunsen in 1842. This great investigation marks an epoch in the history of organic chemistry, and our article would not be complete without at least a short summary of its results. Bunsen started in his investigation with a liquid which had been obtained by Cadet as early as 1760, by the dry distillation of equal parts of white arsenic and anhydrous acetate of potash, and which nobody cared to investigate because it emits fumes which have an indescribably sickening smell and an intensity of poisonous action, compared with which that of white arsenic itself appears insignificant. It was reserved for Bunsen to attack this awful substance and force it to give an account of itself. According to Bunsen, Cadet's liquid is substantially an oxide, $(AsC_2H_6)_2O$, which has strongly basic properties, readily exchanging its O for Cl_2, &c. To obtain the pure substance, the liquor is distilled with corrosive sublimate and hydrochloric acid, which in the first instance yields the pure muriate of the base $As(CH_3)_2Cl$, in the form of a liquid volatile above 100° into vapours which take fire spontaneously in air. From this chloride of kakodyle the pure oxide is obtained by distillation with caustic potash. The pure oxide emits no fumes; its specific gravity is 1·462; it boils near 150°. A mixture of its vapour with air detonates at 50° C. From the chloride again, Bunsen obtained the free radical *kakodyle*, $(AsC_2H_6)_2$, by treatment with metallic zinc in a special apparatus, so constructed that all the several operations involved could be carried out without bringing the contents in contact with air,—a necessary precaution, because kakodyle is a liquid which takes fire in air spontaneously even at ordinary temperatures. Pure kakodyle is a heavy colourless liquid boiling at about 170° C., and freezing at −6°. When exposed to oxygen or chlorine it suffers destructive combustion; but on slow access of air it is oxidized into its oxide, $(AsC_2H_6)_2O$, and kakodylic acid; with chlorine water it unites into the chloride which it came from; it also unites directly with sulphur and other elements; in short, it is exactly to kakodyle compounds what potassium is to potash and potash salts, "a true organic element," as Bunsen himself put it. This discovery of Bunsen's was greeted with an enthusiasm which it is difficult in these days to realize. With us now, a radical is intrinsically a fiction; it was different in 1842. By the isolation of kakodyle the "radical" notion suddenly rose from an unproved hypothesis to the rank of a theory based on experiment. Still, however much our theoretical notions may shift, Bunsen's research will stand as a piece of monumental scientific work.

Kakodylic acid, $As \,.\, O \,.\, (CH_3)_2 \,.\, OH$, is most conveniently prepared from the oxide by addition of water and oxide of mercury,—$H_2O + 2HgO$ supplying the $H_2 + O_3$ required for $1(AsC_2H_6)_2O$. This is a crystalline monobasic acid, soluble in water. Unlike the kakodylides of the $As \,.\, X_3$ type, it has no smell, and is no very violent poison. It takes six grains of it to kill a rabbit.

Metallic Methides.—Examples of these are—$Sb(CH_3)_3$; $Sb(CH_3)_5$; $Mg(CH_3)_2$; $Zn(CH_3)_2$; $Pb(CH_3)_4$; $Al(CH_3)_3$; $Sn(CH_3)_4$. To give an idea of the chemical character of this interesting class of bodies we choose *zinc-methyl* as a representative example, and state briefly the chief points of its chemical history. This body was discovered by Frankland in 1849. It is prepared by boiling iodide of methyl over granulated zinc in a flask connected with an inverted condenser, and so contrived otherwise that the contents are protected against access of moisture and oxygen. Under these circumstances the two ingredients gradually unite into a non-volatile and solid compound $IZn \,.\, (CH_3)$. When this body is heated with more of iodide of methyl, it undergoes decomposition, with formation of iodide of zinc and of dimethyl gas, $I—Zn—CH_3 + CH_3I = ZnI_2 + (CH_3)_2$, which reaction to some extent takes place unavoidably in the preparation of the zinc salt, however great an excess of metal may be taken. What survives needs only to be subjected to dry distillation (in the absence of air) to yield a distillate of zinc-methyl:—

$$2I—Zn—CH_3 = ZnI_2 + Zn(CH_3)_2 \,.$$

Zinc-methyl is a colourless liquid of 1·386 specific gravity at 10°·5, which boils at 46° C.; in contact with air it takes fire. Water decomposes it at once into hydrate of oxide of zinc and marsh gas, $Zn(CH_3)_2 = Zn(OH)_2 + 2CH_3H$. Of other reactions the following may be named. (1) When digested with sodium, it yields a precipitate of metallic zinc, and a double compound of itself and sodium-methyl. This latter unites readily with carbonic acid into acetate of soda, $NaCH_3 + CO_2 = CH_3{-}CO{-}ONa$ (Wanklyn). (2) With chloride of acetyl it forms acetone, $Zn(CH_3)_2 + 2CH_3 . CO . Cl = ZnCl_2 + 2CO(CH_3)_2$ (Freund). (3) Under somewhat different conditions, including the presence of an excess of $Zn(CH_3)_2$, a compound is produced which with water, yields tertiary butyl-alcohol (Boutlerow):

$$CO(CH_3)_2 + Zn(CH_3)_2 = C(CH_3)_3 . O . ZnCH_3 = A;$$
$$A + 2H . OH = Zn(OH)_2 + CH_4 + \underbrace{C(CH_3)_3 - OH}_{\text{Tertiary alcohol.}}$$

(W. D.)

METRONOME, an instrument for denoting the speed at which a musical composition is to be performed. Its invention is generally, but falsely, ascribed to Johann Nepomuk Maelzel, a native of Ratisbon (1772–1838). It consists of a pendulum swung on a pivot; below the pivot is a fixed weight, and above it is a sliding weight that regulates the velocity of the oscillations by the greater or less distance from the pivot to which it is adjusted. The silent metronome is impelled by the touch, and ceases to beat when this impulse dies; it has a scale of numbers marked on the pendulum, and the upper part of the sliding weight is placed under that number which is to indicate the quickness of a stated note, as M.M. (Maelzel's Metronome) 𝅗𝅥 = 60, or ♩ = 72, or ♪ = 108, or the like. The number 60 implies a second of time for each single oscillation of the pendulum,—numbers lower than this denoting slower, and higher numbers quicker beats. The scale at first extended from 50 to 160, but now ranges from 40 to 208. A more complicated metronome is impelled by clock-work, makes a ticking sound at each beat, and continues its action till the works run down; a still more intricate machine has also a bell which is struck at the first of any number of beats willed by the person who regulates it, and so signifies the accent as well as the time.

The earliest instrument of the kind, a weighted pendulum of variable length, is described in a paper by Étienne Loulié (Paris, 1696; Amsterdam, 1698). Attempts were also made by Enbrayg (1732) and Gabory (1771). Harrison, who gained the prize awarded by the English Government for his chronometer, published a description of an instrument for the purpose in 1775. Davaux (1784), Pelletier, Abel Burja (1790), and Weiske (also 1790) described their various experiments for measuring musical time. In 1813 Gottfried Weber, the composer, theorist, and essayist, proposed a weighted ribbon graduated by inches or smaller divisions, which might be held or otherwise fixed at any desired length, and would infallibly oscillate at the same speed so long as the impulse lasted; this, the simplest, is also the surest, the most enduring, the most portable, and the cheapest invention that has come before the world, and one can but wonder that it has not been universally accepted. Stöckel and Zmeskall produced each an instrument; and Maelzel made some slight modification of that by the former, about the end of 1812, which he announced as a new invention of his own, and exhibited from city to city on the Continent. It was, as nearly as can be ascertained, in 1812 that Winkel, a mechanician of Amsterdam, devised a plan for reducing the inconvenient length of all existing instruments, on the principle of the double pendulum, rocking on both sides of a centre and balanced by a fixed and a variable weight. He spent three years in completing it, and it is described and commended in the *Report of the Netherlands Academy of Sciences*, August 14, 1815. Maelzel thereupon went to Amsterdam, saw Winkel and inspected his invention, and, recognizing its great superiority to what he called his own, offered to buy all right and title to it. Winkel refused, and so Maelzel constructed a copy of the instrument, to which he added nothing but the scale of numbers, took this copy to Paris, obtained a patent for it, and in 1816 established there, in his own name, a manufactory for metronomes. When the impostor revisited Amsterdam, the inventor instituted proceedings against him for his piracy, and the Academy of Sciences decided in Winkel's favour, declaring that the graduated scale was the only point in which the instrument of Maelzel differed from his. Maelzel's scale was needlessly and arbitrarily complicated, proceeding by twos from 40 to 60, by threes from 60 to 72, by fours from 72 to 120, by sixes from 120 to 144, and by eights from 144 to 208. Dr Crotch constructed a time-measurer, and Henry Smart (the violinist, and father of the composer of the same name) made another in 1821, both before that received as Maelzel's was known in England. In 1882 James Mitchell, a Scotsman, made an ingenious amplification of the Maelzel clock-work, reducing to mechanical demonstration what formerly rested wholly on the feeling of the performer. Although "Maelzel's metronome" has universal acceptance, the silent metronome and still more Weber's graduated ribbon are greatly to be preferred, for the clock-work of the other is liable to be out of order, and needs a nicety of regulation which is almost impossible; for instance, when Sir George Smart had to mark the traditional times of the several pieces in the Dettingen Te Deum, he tested them by twelve metronomes, no two of which beat together. The value of the machine is exaggerated, for no living performer could execute a piece in unvaried time throughout, and no student could practise under the tyranny of its beat; and conductors of music, nay, composers themselves, will give the same piece slightly slower or quicker on different occasions, according to the circumstances of performance.

METSU, Gabriel, a Dutch painter of celebrity (born in 1630, died after 1667), is one of the few artists of renown in Holland whose life has remained obscure. Houbraken, who eagerly collected anecdotes of painters in the 18th century, was unable to gather more from the gossip of his contemporaries than that, as early as 1658, Metsu, at the age of forty-three, submitted to a dangerous surgical operation. The inference drawn by superficial readers from this statement has been that death immediately ensued. A more careful perusal would have shown that Houbraken knew that Metsu had given lessons to De Musscher in 1665. Local records now reveal that Gabriel was the son of Jacques Metsu, who lived most of his days at Leyden, where he was three times married. The last of these marriages was celebrated in 1625, and Jacomina Garnijers, herself the widow of a painter, gave birth to Gabriel in 1630. Connected by both his parents with art, Metsu was probably taught first by his father and then by Gerard Dow. He probably finished his training under Rembrandt. So far back as 1648, but a few days earlier than Jan Steen, who is said to have painted his portrait, Metsu was registered in the painters' corporation at Leyden; and the books of the guild also tell us that he remained a member in 1649. In 1650 he ceased to subscribe, and works bearing his name and the date of 1653 give countenance to the belief that he had then settled at Amsterdam, where he continued his studies under Rembrandt. His companions at the time would naturally be De Hooch and Van der Meer, whose example he soon followed when it came to his turn to select the class of subjects for which his genius fitted him. Under the influence of Rembrandt he produced the Woman Taken in Adultery, a large picture with the date of 1653, in the Louvre, in which no one would suspect the painter of high life or taverns were it not that his name is written at full length on the canvas. The artist who thus repeated the gospel subjects familiar to

general rising throughout Germany, he expressed in his despatches no distrust of the power of Austria to cope with Napoleon. This is the more singular because, after the disastrous issue of the campaign of 1809, Metternich seems to have taken credit for having opposed the policy of war. Napoleon again captured Vienna; the battle of Wagram was lost; and after a long negotiation Austria had to purchase peace by the cession of part of Austrian Poland and of its Illyrian provinces. Metternich, who had virtually taken Count Stadion's place immediately after the battle of Wagram, was now installed as minister of foreign affairs. The first striking event that took place under his administration was the marriage of Marie Louise, daughter of the emperor Francis, to his conqueror Napoleon. To do justice to Metternich's policy it must be remembered that the alliance of Tilsit between France and Russia was still in existence, and that Austria was quite as much threatened by the czar's designs upon Turkey as by Napoleon's own aggressions. Metternich himself seems, in spite of his denials, to have been the real author of the family union between the houses of Hapsburg and Bonaparte,—a most politic, if not a high-spirited measure, which guaranteed Austria against danger from the east, at the same time that it gave it at least some prospect of security from attack by Napoleon, and enabled Metternich to mature his plans for the contingency of an ultimate breach between France and Russia. In 1812 this event occurred. Metternich, in nominal alliance with Napoleon, sent a small army into southern Russia, allowing it to be understood by the czar that the attack was not serious. Then followed the annihilation of the French invaders. While Prussia, led by its patriots, declared war against Napoleon, Metternich, with rare and provoking coolness, held his hand, merely stating that Austria would no longer regard itself as a subordinate ally, but would act with all its force on one side or the other. The result of this reserve was that Metternich could impose what terms he pleased on Russia and Prussia as the price of his support. The armies of these two powers, advancing into central Germany, proved no match for the forces with which Napoleon took the field in the spring of 1813; and the hard-fought battles of Lützen and Bautzen resulted in the retreat of the allies. After the combatants had made an armistice, Metternich tendered Austria's armed mediation, requiring Prussia to content itself with the restoration of its territory east of the Elbe, and leaving Napoleon's ascendency in Germany almost untouched. Napoleon, after a celebrated interview with Metternich, madly rejected terms so favourable that every Prussian writer has denounced Metternich's proposal of them as an act of bitter enmity to Prussia. On the night of the 10th of August the congress of Prague, at which Austria, as armed mediator, laid down conditions of peace, was dissolved. Metternich himself gave orders for the lighting of the watch-fires which signalled to the armies in Silesia that Austria had declared war against Napoleon. The battle of Leipsic and the campaign of 1814 in France followed, Metternich steadily pursuing the policy of offering the most favourable terms possible to Napoleon, and retarding the advance of the allied armies upon the French capital. Metternich had nothing of that personal hatred towards the great conqueror which was dominant both in Prussia and in England; on the contrary, though he saw with perfect clearness that, until Napoleon's resources were much diminished, no one could be safe in Europe, he held it possible to keep him in check without destroying him, and looked for the security of Austria in the establishment of a balance of power in which neither Russia nor France should preponderate, while Prussia should be strictly confined within its own limits in northern Germany. The assistance of the Austrian army, which was no doubt necessary to the allies, had, so far as related to Prussia, been dearly purchased. When, at the beginning of 1813, Prussia struck for the freedom of Germany, its leading statesmen and patriots had hoped that the result of the war of liberation would be the establishment of German unity, and that the minor German princes, who had been Napoleon's vassals since 1806, would be forced to surrender part of their rights as sovereigns, and submit to a central authority. This dream, however, vanished as soon as Austria entered the field as an ally. It was no part of Metternich's policy to allow anything so revolutionary as German unity to be established, least of all under the influence of Prussian innovators. He made treaties with the king of Bavaria and Napoleon's other German vassals, guaranteeing them, in return for their support against France, separate independence and sovereignty when Germany should be reconstructed. Accordingly, though the war resulted, through Napoleon's obstinate refusal of the terms successively offered to him, in the limitation of France to its earlier boundaries and in a large extension of Prussia's territory, the settlement of Germany outside Prussia proceeded upon the lines laid down by Metternich, and the hopes of unity raised in 1813 were disappointed. A German confederation was formed, in which the minor sovereigns retained supreme power within their own states, while the central authority, the federal diet, represented, not the German nation, but the host of governments under which the nation was divided. Metternich even advised the emperor Francis of Austria to decline the old title of German emperor, disliking any open embodiment of the idea of German unity, and preferring to maintain the ascendency of Austria by a gentle pressure at the minor courts rather than by the avowed exercise of imperial rights. In this unprogressive German policy Metternich was completely successful. His great opponent, Stein, the champion of German unity and of constitutional systems, abandoned his work in despair, and refused the useless post of president of the diet, which Metternich, with a kind of gentle irony, offered to him.

The second branch of Metternich's policy in 1813–14 was that which related to Italy. Following the old maxims of Austrian statesmanship, Metternich aimed not only at securing a large territory beyond the Alps but at making the influence of Austria predominant throughout the Italian peninsula. The promises of national independence which had been made to the Italians when they were called upon to rise against Napoleon were disregarded. In the secret clauses of the first treaty of Paris the annexation of both Lombardy and Venetia was guaranteed to Austria, and the rest of Italy was divided into small states as of old. Napoleon's return from Elba led to the downfall of Murat, who had been allowed to retain the kingdom of Naples, and to the reunion of this country with Sicily, under the Bourbon Ferdinand. After the second overthrow of Napoleon, Metternich endeavoured to make every Italian sovereign enter into a league under Austria's presidency. Ferdinand of Naples accepted the position of vassal, but the pope and the king of Sardinia successfully maintained their independence. With the construction of the German federation, and the partial construction of an Italian federation, both under Austria's guidance, the first part of Metternich's career closes. He had guarded Austria's interests with great skill during the crisis of 1813 and 1814. It was not his own fault, but the fault of ages, that Austria's interests were in antagonism to those of German and of Italian nationality. He thought as an Austrian, and as nothing else; his task was to serve the house of Hapsburg, and this he did with signal ability and success. To denounce Metternich as a kind of criminal, according to the practice

have absolute monarchy restored. The proceedings of the congress at Laibach were a farce. A letter was concocted by Metternich for King Ferdinand to send to his subjects, informing them that the powers would not permit the constitution to exist, and that, in default of their submission, the allied courts would employ force. The British Government, while protesting against the joint action of the three powers as an assumption of international sovereignty, was perfectly willing that Austria, as a state endangered by the Neapolitan revolution, should act on its own account. Metternich, however, continued to treat the Neapolitan question as the affair of Europe, and maintained his concert with Russia and Prussia. Early in 1821 an Austrian force, acting in the name of the allies, entered central Italy. The armies opposed to it collapsed, and the Austrians entered Naples on March 24. But in the meantime a revolution broke out in Piedmont, which threatened to cut off the Austrians from their supports, and to raise all Italy against them. For a moment the bold action of Metternich seemed to have resulted in immense danger both to his own conservative policy and to the peace of Europe; for it was believed that the Piedmontese revolution would be answered, not only by a general Italian movement, but by a rising against the Bourbons in France. The cloud, however, passed away. Order was quickly restored in Piedmont; Lombardy was safely held by Austrian garrisons; and the conclusion of the Italian difficulties, in which Metternich had played a very difficult part with great resolution and dexterity, was his complete and brilliant personal triumph. No statesman in Europe at this moment held a position that could compare with his own.

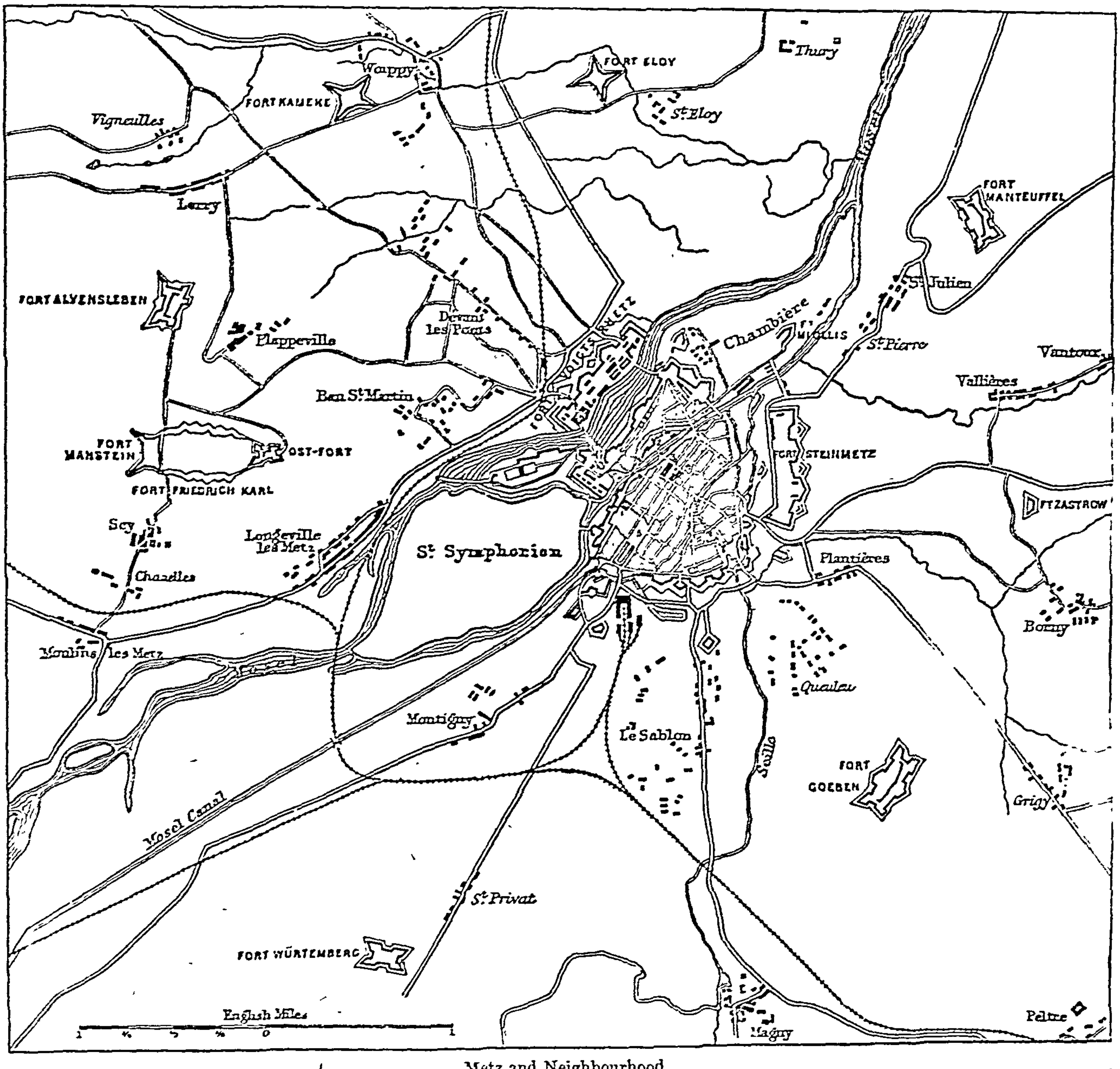
At the congress of Verona, held in 1822, the affairs of Spain were considered by the powers. In the end, the Spanish constitution was overthrown by a French invading army; but, though the arm employed was that of France, the principle of absolutism which animated the crusade was that which Metternich had made his own. A severe check, however, now met him in another quarter. Greece had risen against Turkish rule in 1821. The movement was essentially a national and a religious one, but Metternich treated it as a Jacobinical revolt against lawful authority,—confusing, or affecting to confuse, the struggle for national independence with the shallow and abortive efforts of political liberalism in Italy and Spain. Metternich's attitude towards the Greeks was for some time one of unqualified hostility. If, under the pressure of the Tilsit alliance, he had once been willing that Austria should join Russia in dismembering Turkey, he had now reverted to the principle of maintaining Turkey at all costs against a Russian advance southwards; and he attributed the Greek movement to the efforts of Russian agitators unauthorized by the czar. His desire was that the sultan should deprive Russia of all possible cause for complaint as regarded its own separate interests, and so gain freedom to deal summarily with the Greeks. Metternich's hopes failed, partly through the obstinacy of the Turks, partly through the wavering conduct of Alexander, and partly through the death of Castlereagh and the accession of Canning to power. It was in great part owing to Canning's moral support that Greece ultimately became an independent state; and the extraordinary violence of Metternich's language whenever he mentions this English statesman marks only too well the opposite character of his aims. No politician has left a more damning record against himself than Metternich in his bigoted abuse of Canning. The Greek question, however, was only the first on which the judgment of events was now beginning to declare itself against Metternich and all his principles. The French revolution of 1830 shattered the moral fabric which he had so proudly inaugurated, and in great part himself raised, in 1815. The accord that grew up between England and France now made any revival of the kind of presidency that he had once held in Europe impossible. He was indeed bold and rapid in throwing troops into the papal territory when revolutionary movements broke out there in 1831 and 1832, though war with France seemed likely to result from this step. He was as unsparing as he had been in 1819 in suppressing the agitation which after 1830 spread from France to Germany; and the union of the three eastern courts was once more exhibited in the meeting of the monarchs which took place at Münchengrätz in 1833, and in a declaration delivered at Paris, insisting on their right of intervention against revolution in other countries. It was, however, the new czar of Russia, Nicholas, who was now the real head of European conservatism; and the stubborn character, the narrow, unimaginative mind, of this prince made it impossible for Metternich to shape his purposes by that delicate touch which had been so effective with his predecessor. But in Austria itself Metternich continued without a rival. In 1835 the emperor Francis, with whom he had worked for nearly thirty years, died. Metternich, himself falling into the mental habits of old age, remained at the head of the state till 1848. The revolution of that year ended his political career. He resigned office with the dignity of demeanour which had never failed him; his life was scarcely safe in Vienna, and the old man came for a while to England, which he had not visited since 1794. Living on till June 1859, he saw every great figure of his earlier life, and many that had appeared on the horizon since his own prime, pass away; and a few more months of life would have enabled him to see the end of that political order which it had been his lifework to uphold; for the army of Napoleon III. was crossing the Sardinian frontier at the moment when he died, and before a second summer had gone Victor Emmanuel had been proclaimed king of Italy.

Metternich was a diplomatist rather than a statesman. His influence was that of an expert manager of individuals, not of a man of great ideas. All his greatest work was done before fifty; and at an age when most statesmen are in the maturity of their powers he had become tedious and pedantic. His private character was very lovable. He was an affectionate if not a faithful husband, a delightful friend, and a most tender father. The excessive egotism which runs through his writings gives perhaps an impression of weakness which did not really belong to his nature. Drawn by a firmer pen, the scene in which he describes himself labouring in the German conferences of 1820, while his favourite daughter was dying in an adjoining room, would have been one of the most affecting things in political biography. The man who could so have worked and felt together must have possessed no ordinary strength of character, no common force of self-control.

The collection of Metternich's writings published by his family under the title of *Denkwurdigkeiten*, along with French and English editions, contains letters and despatches of great value. The autobiography is not always trustworthy, and must be read with caution. Gentz's correspondence is of first-rate importance for the years 1813–30. Original papers are also contained in various German works upon particular events or movements, as in Oncken for the negotiations of 1813; Welcker, Aegidi, Nauwerck for German affairs in 1819 and following years; Prokesch von Osten for Eastern affairs. (C. A. F.)

METZ, the capital of German Lorraine, and one of the strongest fortresses in Europe, is situated at the confluence of the Moselle and the Seille, 80 miles to the north-west of Strasburg, and 190 miles to the east of Paris. It is the seat of a military governor, the judicial and administrative authorities of Lorraine, a Roman Catholic bishop,

Protestant and Jewish consistories, and a chamber of commerce. The general appearance of the town is quaint and irregular, but there are also many handsome modern streets. The Moselle flows through it in several arms, crossed by fourteen or fifteen bridges. In the south-west corner of the town is the esplanade, an extensive open space commanding a fine view of the fertile "Pays Messin" around Metz. The most interesting of the ten city gates is the Porte d'Allemagne or Deutsches Thor, a castellated structure erected in 1445, and still bearing traces of the siege of Charles V. Metz contains seven Roman Catholic churches, two Protestant churches, and a synagogue. The cathedral, with huge pointed windows, slender columns, and numerous flying buttresses, was begun in the 13th century, and finished in 1546, and belongs to the decadence of the Gothic style. The Gothic churches of St Vincent and St Eucharius, and the handsome garrison-church, completed in 1881, also deserve mention. Among secular buildings the most important are the large covered market, the town-hall, the palace of justice, the theatre, the governor's house, and the various buildings for military purposes. The public library contains 35,000 volumes, including an



Metz and Neighbourhood.

1. Palace of Justice. 2. Prefecture. 3. Cathedral. 4. Town-Hall and Governor's House.

extensive collection of works relating to the history of Lorraine. In the same building is the museum, which contains a picture gallery, a numismatic cabinet, and a collection of specimens of natural history. Metz also possesses several learned societies and charitable institutions, a gymnasium, three seminaries, and a military academy. The cemetery of Chambière contains the graves of 8400 French soldiers who died here in 1870.

The commerce and industry of Metz have not yet entirely recovered from the blow inflicted by the withdrawal of French capital in 1871. The principal articles of manufacture are leather, coarse cloth and canvas, gunpowder, arms, needles, billiard tables, hats, and artificial flowers. There are several large iron-works in the neighbourhood. The trade of Metz is chiefly carried on in leather, timber, wine, brandy, liqueurs, beer, preserved fruits, and hardwares. A large annual fair is held here. The civil population of Metz, which in 1869 amounted to 48,066, sank in 1872 to 33,134. Since then it has steadily increased, and in 1881 was 43,275, about half of whom were Germans. The garrison of Metz consists of 10,000 men, or including the surrounding forts nearly 16,000. The total of 58,813 includes 17,000 Protestants and 1600 Jews.

History.—Metz, the Gallic Divodurum, was the chief town of the Mediomatrici, and was also called by the Romans Mediomatrica, a name from which the present form has been derived by contraction. Cæsar describes it as one of the oldest and most important towns in Gaul. The Romans, recognizing its strategical importance, fortified it and supplied it with water by an imposing aqueduct, the remains of which still exist. Under the Roman emperors Metz was connected by military roads with Toul, Langres, Lyons, Strasburg, Verdun, Rheims, and Treves. Christianity was introduced in the 3d century of our era. In the middle of the 5th century the town was plundered by the Huns under Attila; subsequently it came into the possession of the Franks; and in 512 it was made the capital of Austrasia. On the partition of the Carolingian realms in 843 Metz fell to the share of the western kingdom as the capital of Lorraine. Its bishops, whose creation reaches back to the 4th century, now began to be very powerful. Metz acquired the privileges of a free imperial town in the 12th century, and attained great commercial prosperity. In 1552 it fell into the hands of the French through treachery, and was heroically and successfully defended against Charles V. by the young duke of Guise. It now sank to the level of a French provincial town, and its population dwindled from 60,000 to 22,000 (1698). At the peace of Westphalia Metz, with Toul and Verdun, was formally ceded to France, in whose possession it remained for upwards of two centuries. In August 1870 the successes of the German troops compelled Marshal Bazaine and the French army of the Rhine to seek shelter behind the fortifications of Metz, which was forthwith subjected by the Germans to a rigorous blockade. After an investment of ten weeks, during which not a single shot was fired at the town, Bazaine capitulated, surrendering to the victors an army of nearly 180,000 men, several hundred cannon, and an immense quantity of military stores of all kinds. By the peace of Frankfort in 1871 Metz was again united to the German empire. Marshal Fabert and Generals Custine and Kellermann were natives of Metz.

As a fortress Metz has always been of the highest importance, and it now ranks with Strasburg as one of the two great bulwarks of the west frontier of Germany. The original town-walls were replaced by ramparts in 1550, and the citadel was built in 1566. In 1674 the works were reconstructed by the celebrated military engineer Vauban. Under Napoleon III. the fortress was strengthened to meet the demands of modern warfare, and since 1871 the Germans have spared neither time nor money in completing and supplementing his plans. The present fortifications of Metz consist of two lines—an inner circle of bastions and ramparts enclosing the city itself, and an outer circle of large detached forts on the surrounding hills. The inner line is strengthened by two citadels, one of which is advanced as a tête-de-pont on the left bank of the Moselle. The outer circle consists of nine or ten large forts, connected with each other by smaller fortifications and commanding all the approaches to the city. They form a large fortified camp with a circumference of 15 miles, within which are twelve villages and numerous country-houses and farms. The most distant of the outlying forts is about 3½ miles from the cathedral. Their names and positions may be seen on the annexed plan. Previous to 1870 the fortress of Metz had never succumbed to an enemy.

Sources of Information.—Westphal, *Geschichte der Stadt Metz*, 1875-78; Georg Lang, *Metz und seine Umgebungen*, 1883, and *Statistisch-topographisches Handbuch für Lothringen*. The official German account of the blockade of Metz in 1870 will be found in the history of the Franco-German war issued by the general staff at Berlin, 1872 *sq.* A succinct account is given by Georg Lang, *Die Kriegsoperationen um Metz im Jahr* 1870, 2d ed., Metz, 1880.

MEULEN, Antony Francis van der (1634–1690), was called to Paris about 1666 by Colbert, at the instance of Le Brun, to fill the post of battle painter to Louis XIV. Born in 1634 at Brussels, he had at an early age eclipsed his master Peter Snayers, and the works executed by him for the king of France during the campaigns of Flanders (1667) so delighted Louis that from that date Van der Meulen was ordered to accompany him in all his expeditions. In 1673 he was received into the French Academy, and attained the grade of councillor in 1681. Lodged in the Gobelins, richly pensioned, and loaded with honours, he died at Paris in 1690. Detached works from his hand are to be seen in various collections, but he is best represented by the series of twenty-three paintings, mostly executed for Louis XIV., now in the Louvre. They show that he always retained his Flemish predilections in point of colour, although in other respects his style was modified by that of the French school.

See *Mém. inédit. Acad. de Peinture*, 1854; Descamps, *Vies des Peintres Flamands*.

MEURTHE-ET-MOSELLE, a department in the north-east of France, formed in 1871 out of those parts of the old departments of Meurthe and Moselle which continued French, and deriving its name from the two principal rivers which water it. Prior to 1790 it belonged to ancient Lorraine, or to one or other of the bishoprics of Toul, Metz, and Verdun. It lies between 5° 25′ and 7° 5′ E. long. and 48° 25′ and 49° 5′ N. lat., and is bounded on the E. by Alsace-Lorraine, on the N. by Belgium and the grand-duchy of Luxemburg, on the W. by the department of Meuse, and on the S. by that of Vosges. The superficial area is 2020 square miles. Geologically Meurthe-et-Moselle has five well-marked regions following each other in regular succession from east to north-west. On the frontier of Alsace are the Vosges mountains, of Trias sandstone (*grès Vosgiens*), with a maximum elevation of 3000 feet. A narrow band of variegated sandstone divides the Vosges from the second region, formed of shelly limestone, which extends as far as the Meurthe on the north and the Moselle on the west. The third region is formed by the variegated marls which cover the rich saline strata of the neighbourhood of Nancy. The Jura limestones of the Lias and Oolite, to the north-west and west of the department, form the last two regions. Here there is a maximum elevation of 1400 feet, and the plateau of Briey stretches out towards that of the Ardennes. Between the Vosges and the Ardennes the valley of the Moselle runs from south to north, forming the main artery of the department; the lowest level (570 feet) occurs where the river leaves it. Only a small part of the drainage of Meurthe-et-Moselle flows into the Meuse. The Moselle runs north-west from its entrance into the department as far as Toul; north-east from Toul to Frouard, where it receives its principal affluent, the Meurthe, and becomes navigable; north from Frouard to Pagny-sur-Moselle, passing to Pont à Mousson. The principal affluents of the Moselle are the Madon and the Orne on the left, and on the right, besides the Meurthe, the Seille, which in one part of its course forms the boundary of Alsace-Lorraine. The Meurthe, which flows to the north-west from Raon l'Étape to Frouard, passes on to Baccarat, Lunéville, St Nicholas, and Nancy, and is swelled on the right by the Vezouse and the Sanon, and on the left by the Mortagne. The principal tributary of the Meuse within the department is the Chiers, which takes its course by Longwy and Longuyon. Climatologically Meurthe-et-Moselle belongs to the Vosgian region. Its mean annual temperature is 52° Fahr., being 2° Fahr. lower than that of Paris (which has the same latitude). The thermometer in severe winters falls to 13° Fahr., while in summer it reaches 100° Fahr. This is to be accounted for by the general elevation of the department, the proximity of the mountains, the arrangement of the valleys (which lie open towards the north), and the distance from the sea.

More than half of the department consists of culturable land, one-fourth of forests, and one-tenth of meadow land. In 1878 there were 54,346 horses, more than 100,000 sheep, 85,000 pigs, 74,000 cattle, 15,000 goats, 21,000 dogs, and 17,000 hives of bees. The crops for the same year amounted to 454,192 quarters of wheat, 37,500 quarters of barley, 35,078 quarters of rye, 570,884 quarters of oats, 9,079,125 bushels of potatoes, and 76,868 tons of beet-root. Hops, tobacco, colza, hemp, and flax also occupy a considerable area. The annual yield of the vineyards (56 square miles in extent) exceeds £900,000; the wines of Toul are the best. The most common fruit trees are the pear, the apple, the walnut, the cherry, and the plum. Of forest trees the oak and the wych-elm are most frequent in the west of the department, the beech and the fir in the Vosges. The French school of forestry has its seat at Nancy. The metallurgic industry is highly developed, and has made very rapid progress within the last few years. Even in 1872 there was a consumption of 350,000 tons of coal, four-fifths of which came from Saarbruck, and the remaining fifth from Belgium. In 1877 the iron ore obtained amounted to 1,000,000 tons, of which two-thirds came from the beds near Nancy, the remainder from the neighbourhood of Longwy. In 1880 the department produced a third of the pig-iron made in France (more than 500,000 tons).

In 1877 the yield was 43,000 tons. Besides blast-furnaces, forges, and rolling-mills, there are manufactories of files and boring tools, agricultural implements, and furniture. In the production of salt the department holds the first rank in France; the salt-bearing tracts cover more than 150 square miles, the beds having a mean thickness of 65 feet. The principal salt-working centres (St Nicolas, Varangeville, and Rosières-aux-Salines) lie between Nancy and Lunéville; the annual value of rock-salt and refined salt produced exceeds £500,000; subsidiary to this production is an important manufacture of soda salts. The other chemical products are prussiate of potash, bone-black, wax-candles, soap, and matches. Stone quarrying and the manufacture of plaster and lime are also important branches of industry. The flint-glass manufactory of Baccarat, which employs nearly 1500 workmen, is well known; that of plate-glass at Cirey (with 1000 workmen) produces plates of great size. The faience manufactories of Lunéville, Toul, and Longwy are important. Mention may also be made of the manufacture of window-glass, watch-glasses, and drinking-glasses. The tobacco manufacture at Nancy employs 1000 workmen; tanning, glove-making, hat-making in felt and straw, wool-spinning, and the manufacture of army clothing are also carried on. Nancy is renowned for its embroidery, which is, however, diminishing in importance. It also possesses factories for cotton spinning and cotton stuffs, and for hosiery. The starch manufactories and the breweries, especially that of Tantonville, the largest in France, are highly productive. Nancy also carries on distilleries, grain-mills, paper-mills, manufactories of pasteboard objects, and a large printing establishment. The commerce of the department is effectively served by 300 miles of railway (the principal line being that from Paris to Strasburg through Nancy), by a number of good roads, and by several navigable rivers and canals. The main waterway is formed by the canal between the Marne and the Rhine, which runs by Toul and Nancy, and traverses the department from west to east. This canal communicates with the Moselle, which is navigable from Frouard downwards, and with the new eastern canal, which reascends the Moselle as far as Épinal, and which is intended to unite the Meuse and the Moselle with the Saône and the Rhone. The population of Meurthe-et-Moselle in 1881 was 419,317 inhabitants. It constitutes the diocese of Nancy, has its court of appeal at Nancy, and forms a part of the district of the 6th army corps (Châlons-sur-Marne). There are 4 arrondissements (Nancy, Briey, Lunéville, and Toul), 29 cantons, and 597 communes. The capital is Nancy, and the other principal towns are Pont à Mousson, formerly the seat of a university; Longwy (5064), a fortified place; and Baccarat (6013), celebrated for its glass-works.

MEUSE, MAESE, or MAAS, a river of France, Belgium, and Holland, discharging into the North Sea or German Ocean, has a course (variously measured) of some 500 or 550 miles, about 300 miles lying within France. Rising in the department of Haute-Marne (1342 feet), at a point where the plateau of Langres borders on the Monts Faucilles, it follows a winding course, first from south to north, then to north-west, and afterwards to north, across the departments of Vosges, Meuse, and Ardennes, passing by Neufchateau, Vaucouleurs, Commercy, St Mihiel, Verdun, Sedan, Mézières, and Givet. Naturally navigable below Verdun, it has been made so from Troussey, where it meets the canal which unites the Marne to the Rhine, and from this point to Liége it admits vessels of from 6 to 7 feet draught. After traversing a wide valley covered by green meadows, the Meuse, below Mézières, flows through narrow gorges confined between rocky walls 200 or 300 feet high, formed by the plateau of the Ardennes. The hills of the Argonne, by which it is hemmed in on its upper course, prevent its receiving any important affluent before the Chiers and the Semoy, which both fall into it on the right in the Ardennes. At the point where it leaves France its ordinary volume is about 1000 cubic feet. In Belgium it runs picturesquely between the districts of Famenne and Condroz on the right, and those of Les Fagnes and Hesbaye on the left. Above Dinant it receives the Lesse, whose valley is celebrated for its wonderful grottoes, and at the foot of the citadel of Namur it is joined on the left by its principal affluent, the Sambre, whose north-easterly direction it takes. It then takes its course through the busy valley in which Huy, Seraing, and Liége are situated, receiving the Ourthe on its right. Resuming a northerly direction, then taking one to the north-west, and finally one to the west, the Meuse passes in front of the Dutch citadel of Maestricht to Roermonde, so called from its confluence there with the Roer, and to Venlo, where the canal between the Meuse and the Scheldt begins. Flowing thence through an absolutely unbroken plain, it finally joins the Rhine, to which it gives its own name, although the volume of its waters is twenty times less than that of the German river. It is at Gorcum that the Waal, the first separate arm of the Rhine, brings to the Meuse two-thirds of the waters of that river. The Meuse soon after divides into two branches. While the Merwede flows due west, the southern arm falls into the Biesbosch, an estuary of the sea, formed four hundred and fifty years ago by an irruption of the sea over a country then cultivated and thickly peopled, and now the subject of attempts at reclamation. On reaching Dordrecht, where the river navigation and sea navigation meet, and where the rafts which come down from the Black Forest are broken up, the Meuse again divides into two arms. The Old Meuse flows due west, while the northern arm joins the Lek, a second branch of the Rhine, and continues its course to Rotterdam. This is the most important branch of the estuary of the Meuse, and efforts are being made to regulate and deepen its channel by constructing one of those grand canals in which the Dutch are so skilful. Schiedam and Vlardingen, both on the right, are the last places of importance on the banks of the river.

MEUSE, a department in the north-east of France, formed out of a part of Lorraine and portions of the Three Bishoprics, the Clermontais, and Champagne, derives its name from the river by which it is traversed from south to north. It lies between 4° 52′ and 5° 50′ E. long., and between 48° 25′ and 49° 38′ N. lat., and is bounded on the N. by Belgium and the department of Ardennes, on the E. by that of Meurthe-et-Moselle, on the S. by those of Vosges and Haute-Marne, and on the W. by those of Marne and Ardennes. Of its superficial area (2405 square miles), about one-half belongs to the basin of the Meuse, which is enclosed to the east and west by the eastern and western Argonnes. On the north-east it is watered by the Orne, a tributary of the Moselle, and the Chiers, which runs by Montmédy, and joins the Meuse a little beyond the northern limit of the department. The other half sends its waters to the Seine through the Aire, a tributary of the Aisne, both of which take their rise here, and by the Ornain, an affluent of the Saux, these two last being tributary to the Marne. The Meuse receives no important river in its course through this department. The highest elevation (1388 feet) occurs to the south-west, on the line of the ridge which separates the basin of the Meuse from that of the Seine. The heights gradually sink from south to north, but seldom fall below 1000 feet. The hills of the western Argonne similarly sink rapidly down to the valley of the Saux, where the lowest level of the department (377 feet) is reached. The climate of Meuse is transitional between the region of the Seine and that of the Vosges; its winters are less severe than those of the latter, but it is not so temperate as the former. The mean annual temperature is 52° Fahr. As at Paris, the maximum cold is 9° Fahr.; the greatest heat rarely exceeds 95° Fahr.

More than half the surface of the department consists of culturable lands, one-fourth of forest, one-tenth of meadow land. The proportion of horses is larger than in any other French department, except La Manche. There are 53,800 horses, 90,000 cattle, 145,000 sheep, 125,000 pigs, and nearly 30,000 beehives. Cereals, potatoes, and beet-root are the chief crops (in 1877 465,966 quarters of wheat, 104,660 quarters of barley, 585,355 quarters of oats, 7,677,374 bushels of potatoes, besides pulse, hemp, and colza). The vineyards produced more than 6,600,000 gallons of wine of good quality. The forests, which are principally of oak, are rich in game, as are the rivers in fish. The mineral wealth of the depart-

ment includes iron ore, good freestone, and fossil phosphates of lime. There are blast-furnaces, iron, copper, and bell foundries, wire-works, and manufactories of files, hardware, and edge tools. The cotton-spinning factories employ 15,000 spindles and 32,000 frames; the woollen manufacture employs 5000 spindles, and some hundreds of persons are employed in the spinning and weaving of hemp, flax, and jute. The glass-works (particularly the manufactory of painted window-glass, transferred after the war of 1870 from Metz to Bar-le-Duc), paper-mills, saw-mills, and flour-mills, as well as the manufactures of lime, tiles, and fire-bricks, are worthy of mention. Hosiery and embroidery also give occupation to a great number of workshops, and the department is celebrated for its confectionery. Meuse contains more than 300 miles of railway,—the principal lines being that from Paris to Strasburg through Bar-le-Duc and Commercy, that from Paris to Metz through Verdun, and the branch line to the Meuse. The chief waterways are the canal connecting the Marne with the Rhine, and the canal of the Meuse; the two together have a length of 146 miles. The population of the department in 1881 was 289,861,—a small number in proportion to its extent, and with a tendency to decrease. Ecclesiastically it forms the diocese of Verdun; it has its court of appeal at Nancy, and constitutes part of the district of the army corps of Châlons-sur-Marne. There are 4 arrondissements,—Bar-le-Duc, Commercy, Montmédy, and Verdun,—28 cantons, and 586 communes. Bar-le-Duc (population in 1881, 17,485) is the capital; Commercy has 5260 inhabitants and Montmédy 3000; St Mihiel (5915), on the Meuse, has good churches and some remarkable rocks, and is the seat of the departmental assize court.

MEXICO

I. ANCIENT MEXICO.

THE name Mexico is connected with the name of the group of American tribes calling themselves *Mexica* (sing. *Mexicatl*), or *Azteca*. The word is related to or derived from the name of the Mexican national war-god Mexitl, better known as Huitzilopochtli. The Aztecs from the 12th century appear to have migrated from place to place over the mountain-walled plateau of *Anahuac*, the country "by the water," so called from its salt lagoons, and which is now known as the valley of Mexico. About 1325 they founded on the lake of Tezcuco the permanent settlement of Mexico Tenochtitlan, which is still represented by the capital city Mexico. The name Mexico was given by the Spanish conquerors to the group of countries over which the Aztec power more or less prevailed at the time of the European invasion. Clavigero (*Storia Antica del Messico*, vol. i.) gives a map of the so-called "Mexican empire," which may be roughly described as reaching from the present Zacatecas to beyond Guatemala; it is noticeable that both these names are of Mexican origin, derived respectively from words for "straw" and "wood." Eventually Mexico and New Mexico came to designate the still vaster region of Spanish North America, which (till cut down by changes which have limited the modern republic of Mexico) reached as far as the Isthmus of Panama on the south and took in California and Texas on the north. Mexico in this wide sense is of high interest to the anthropologist, from the several native American civilizations which appear within its limits, and which conveniently if loosely group themselves round two centres, the Mexican proper and the Central American.

When early in the 16th century the Spaniards found their way from the West India Islands to this part of the mainland of America, they came in view of nations cultured high above the level they had hitherto met with in the New World. Here were not rude and simple tribes like the islanders of the Antilles, but nations with organized armies, official administrators, courts of justice, high agriculture and mechanical arts, and, what struck the white men especially, stone buildings whose architecture and sculpture were often of dimensions and elaborateness to astonish the builders and sculptors of Europe. How a population of millions could inhabit a world whose very existence had been till then unknown to geographers and historians, and how its nations could have reached so high a grade of barbaric industry and grandeur, was a problem which naturally excited the liveliest curiosity of scholars, and gave rise to a whole literature. Hernandez and Acosta shared the opinion of their time that the great fossil bones found in Mexico were remains of giants, and it was argued that, as before the deluge there were giants on the earth, therefore Mexico was peopled from the Old World in antediluvian times. On the other hand the multitude of native American languages suggested that the migration to America took place after the building of the tower of Babel, and Siguenza arrived at the curiously definite result that the Mexicans were descended from Naphtuhim, son of Mizraim and grandson of Noah, who left Egypt for Mexico shortly after the confusion of tongues. Although such speculations have fallen out of date, it is to be remembered in their favour that they were stepping-stones to more valid argument; especially they induced the collection of native traditions and invaluable records of races, languages, and customs, which otherwise would have been lost for ever. Even in the present century Lord Kingsborough was led to spend a fortune in printing a magnificent compilation of Mexican picture-writings and documents in his *Antiquities of Mexico* by his zeal to prove the theory advocated by Garcia a century earlier, that the Mexicans were the lost tribes of Israel.

Real information as to the nations of Mexico before Spanish times is very imperfect, but not altogether wanting. It is derived partly from inspection of the natives themselves, their languages and customs, which may be now briefly considered, before going on to the recollections handed down in the native picture-writings and oral traditions. The remarks made by the accurate and experienced observer Alexander von Humboldt, who had seen more American tribes than almost any traveller, are still entitled to the greatest weight. He considered the native Americans of both continents to be substantially similar in race-characters. Such a generalization will become sounder if, as is now generally done by anthropologists, the Eskimo with their pyramidal skulls, dull complexion, and flat noses are removed into a division by themselves. Apart from these polar nomads, the American indigenes group roughly into a single race or division of mankind, of course with local variations. If our attention is turned to the natives of Mexico especially, the unity of type will be found particularly close. The native population of the plateau of Mexico, mainly Aztecs, may still be seen by thousands without any trace of mixture of European blood; and the following description may give a fair idea of their appearance.[1] Their stature is somewhat low, estimated about 5 feet 3 inches, but they are of muscular and sturdy build. Measurements of their skulls show them mesocephalic (index about 78), or intermediate between the dolichocephalic and brachycephalic (narrow and wide skulled) types of mankind. The face is oval, with low forehead, high cheek-bones, long eyes sloping outward towards the temples, fleshy lips, nose wide and in some cases flattish but in others aquiline, coarsely moulded features, with a somewhat stolid and gloomy expression. Thickness of skin, masking the muscles, has been thought the cause of a peculiar heaviness in the outlines of body and face; the complexion varies from yellow-brown to chocolate (about 40 to 43 in the anthropological

[1] References may be found in Bancroft, *Native Races of the Pacific States*, vol. i. pp. 24, 573, 618, 646.

scale); eyes black; straight coarse glossy black hair; beard and moustache scanty. Among variations from this type may be mentioned higher stature in some districts, and lighter complexion in Tehuantepec and elsewhere. If now the native Americans be compared with the races of the regions across the oceans to their east and west, it will be seen that their unlikeness is extreme to the races eastward of them, whether white Europeans or black Africans. On the other hand they are considerably like the Mongoloid peoples of North and East Asia (less so to the Polynesians); so that the tendency among anthropologists is now generally to admit a common origin, however remote, between the tribes of Tartary and of America. This original connexion, if it may be accepted, would seem to belong to a long-past period, to judge from the failure of all attempts to discover an affinity between the languages of America and Asia. At whatever date the Americans began to people America, they must have had time to import or develop the numerous families of languages actually found there, in none of which has community of origin been satisfactorily proved with any other language-group, at home or abroad. In Mexico itself the languages of the Nahua nations, of which the Aztec is the best-known dialect, show no connexion of origin with the language of the Otomi tribes, nor either of these with the languages of the regions of the ruined cities of Central America, the Quiché of Guatemala and the Maya of Yucatan. Indeed, within the Mexican limits, there are various other languages which, so far as philological research can at present decide, are independent of one another. The remarkable phenomenon of nations so similar in bodily make but so distinct in language can hardly be met except by supposing a long period to have elapsed since the country was first inhabited by the ancestors of peoples whose language has since passed into so different forms. The original peopling of America may well date from the time when there was continuous land between it and Asia.

It would not follow, however, that between these remote ages and the time of the discovery of the New World by Columbus no fresh immigrants can have reached America. We may put out of the question the Scandinavian searovers who sailed to Greenland about the 10th century, and appear afterwards to have coasted New England (see AMERICA, vol. i. p. 706), but do not seem to have found their way far enough southward for their visit to have any effect on Mexico. But at all times communication has been open from East Asia and even the South Sea islands to the west coast of America. The importance of this is evident when we consider that Japanese junks now drift over by the ocean current to California at the rate of about one a year, often with some of the crew still alive (see C. W. Brooks in Bancroft, vol. v. p. 51; *Overland Monthly*, San Francisco, 1872, p. 353). Further north, the Aleutian islands offer a line of easy sea passage, while in north-east Asia, near Behring's Strait, live Chukchi tribes who carry on intercourse with the American side; the presence of Eskimo in this part of Asia (see Nordenskiöld, *Voy. of Vega*, vol. ii. pp. 13, 81) is so plainly due to local migration that it is neglected in comparing the languages of the two continents. Asiatics such as Japanese or Kurile Islanders, if they found their way in small numbers to America and merged into native tribes, might hardly leave descendants distinguishable from the rest of the population even in the first generation, nor introduce their own language. Such assertions as that the Guatusos of Costa Rica are a tribe with fair skin and flaxen hair, and that Japanese words may be detected among the Indians of British Columbia, are examples of evidence which may be worth further sifting; but in an account like the present no proofs can be admitted unless far better authenticated than these. What gives a more solid interest to the question of Asiatic influence in America, is that, though neither the evidence of features nor of language has substantiated it, there are details of Mexican civilization which are most easily accounted for on the supposition that they were borrowed from Asia. They do not seem ancient enough to have to do with a remote Asiatic origin of the nations of America, but rather to be results of comparatively modern intercourse between Asia and America, probably since the Christian era. Humboldt (*Vues des Cordillères*, pl. xxiii.) compared the Mexican calendar with that in use in eastern Asia. The Mongols, Tibetans, Chinese, and other neighbouring nations have a cycle or series of twelve animals, viz., rat, bull, tiger, hare, dragon, serpent, horse, goat, ape, cock, dog, pig, which may possibly be an imitation of the ordinary Babylonian-Greek zodiac familiar to ourselves. The Mongolian peoples not only count their lunar months by these signs, but they reckon the successive days by them, rat-day, bull-day, tiger-day, &c., and also, by combining the twelve signs in rotation with the elements, they obtain a means of marking each year in the sixty-year cycle, as the wood-rat year, the fire-tiger year, &c. This method is highly artificial, consisting, not in mere numbering, but in combining series of different terms so that the same combination does not recur till the end of the period. Thus the reappearance of its principle in the Mexican and Central-American calendar (see p 212) is suggestive of importation from Asia. Humboldt also discussed the Mexican doctrine, represented in the native pictures, of four ages of the world belonging to water, earth, air, and fire, and ending respectively by deluge, earthquake, tempest, and conflagration. The resemblance of this to some versions of the Hindu doctrine of the four ages or yuga is of so remarkable a closeness as hardly to be accounted for except on the hypothesis that the Mexican theology contains ideas learnt from Asiatics. Among Asiatic points of resemblance to which attention has since been called is the Mexican belief in the nine stages of heaven and hell, an idea which nothing in nature would suggest directly to a barbaric people, but which corresponds to the idea of successive heavens and hells among Brahmans and Buddhists, who apparently learnt it (in common with our own ancestors) from the Babylonian-Greek astronomical theory of successive stages or concentric planetary spheres belonging to the planets, &c. The Spanish chronicles also give accounts of a Mexican game called *patolli*, played at the time of the conquest with coloured stones moved on the squares of a cross-shaped figure, according to the throws of beans marked on one side; the descriptions of this rather complicated game correspond closely with the Hindu backgammon called *pachisi* (see Tylor in *Jour. Anthrop. Inst.*, vol. viii. p. 116).[1]

The native history of Mexico and Central America is entitled to more respect than the mere recollections of savage tribes, inasmuch as here memory was aided by something like written record. The Mexican pictures so far approached writing proper as to set down legibly the names of persons and places and the dates of events, while the rude drawings which accompanied these at least helped the professional historians to remember the traditions repeated orally from generation to generation. Thus actual documents of native Aztec history, or copies of

[1] The appendix to Prescott's *Conquest of Mexico* contains an interesting summary of analogies between the civilization of Mexico and that of the Old World, but some of the arguments are very inconclusive. One which has been often cited turns on the likeness alleged by Nazera between the Chinese language and that of the Otomi nation of Mexico (whose name survives in that of their town Otompan, now Otumba). The examination of an Otomi grammar (such as *Éléments de la Grammaire Othomi*, Paris, 1863) will, however, convince the philological reader that the resemblance is hardly of an amount to found a theory of a Chinese connexion upon.

them, are still open to the study of scholars, while after the conquest interpretations of these were drawn up in writing by Spanish-educated Mexicans, and histories founded on them with the aid of traditional memory were written by Ixtlilxochitl and Tezozomoc; the most important of these picture-writings, interpretations, and histories may be found in Kingsborough's *Antiquities of Mexico*. In Central America the rows of complex hieroglyphs to be seen sculptured on the ruined temples probably served a similar purpose up to the time of the Spanish invasion. The documents purporting to be histories, written down by natives in later times, thus more or less represent real records of the past, but the task of separating the preponderant mythical part from what is real history is of the utmost difficulty. Among the most curious documents of early America is the *Popol-Vuh* or national book of the Quiché kingdom of Guatemala, a compilation of traditions written down by native scribes, found and translated by Father Ximenez about 1700, and published by Scherzer (Vienna, 1857) and Brasseur de Bourbourg (Paris, 1861). This book, composed in a picturesque barbaric style, begins with the time when there was only the heaven with its boundaries towards the four winds, but as yet there was no body, nothing that clung to anything else, nothing that balanced itself or rubbed together or made a sound; there was nought below but the calm sea alone in the silent darkness. Alone were the Creator, the Former, the Ruler, the Feathered Serpent, they who give being and whose name is Gucumatz. Then follows the creation, when the creators said "Earth," and the earth was formed like a cloud or a fog, and the mountains appeared like lobsters from the water, cypress and pine covered the hills and valleys, and their forests were peopled with beasts and birds, but these could not speak the name of their creators, but could only chatter and croak. So man was made first of clay, but he was strengthless and senseless and melted in the water; then they made a race of wooden mannikins, but these were useless creatures without heart or mind, and they were destroyed by a great flood, and pitch poured down on them from heaven, those who were left of them being turned into the apes still to be seen in the woods. After this comes the creation of the four men and their wives who are the ancestors of the Quichés, and the tradition records the migrations of the nation to Tulan, otherwise called the Seven Caves, and thence across the sea, whose waters were divided for their passage. It is worth while to mention these few early incidents of the national legend of Guatemala, because their Biblical incidents show how native tradition incorporated matter learnt from the white men. Moreover, this Central-American document, mythical as it is, has an historical importance from its bringing in names belonging also to the traditions of Mexico proper. Thus Gucumatz, "Feathered Serpent," corresponds in name to the Mexican deity Quetzalcoatl; Tulan and the Seven Caves are familiar words in the Aztec migration-traditions, and there is even mention of a chief of Toltecat, a name plainly referring to the famed Toltecs, of whom further account will be given in their place in Mexican history. Thus the legends of the *Popol-Vuh* confirm what is learnt from comparing the culture of Central America and Mexico proper, that, though the nations of these districts were not connected by language, the intercourse and mixture between them had been sufficient to implant in them much common civilization, and to justify the anthropologist in including both districts in one region. Historical value of the ordinary kind may be found in the latter part of the *Popol-Vuh*, which gives names of chiefs down to the time when they began to bear Spanish names, and the great city of Quiché became the deserted ruin of Santa Cruz. The Maya district of Yucatan has also some vestiges of native traditions in the manuscript translated by D. Pio Perez (in Stephens, *Incidents of Travel in Yucatan*) and in the remarkable 16th century *Relacion de las Cosas de Yucatan* by Diego de Landa, published by Brasseur de Bourbourg (Paris, 1864). As in the Guatemala traditions, we hear of ancient migration from the Mexican legendary region of Tula; and here the leaders are four famous chiefs or ancestors who bear the Aztec name of the Tutul-Xiu, which interpreted means "Bird-Tree." Unfortunately for the historical standing of these four ancestors, there are in the Aztec picture-writings representations of four trees each with a bird perched on it, and placed facing the four quarters, which make it probable that the four Tutul-Xiu of tradition, in spite of the circumstantial detail of their wars and migrations, may be only mythic personifications of the four cardinal points (see Schultz-Sellack in *Zeitsch. f. Ethn.*, 1879, p. 209). Nevertheless, part of the later Maya records may be genuine,—for instance, when they relate the war about three centuries before the Spanish conquest, when the king of Chichen-Itza destroyed the great city of Mayapan. Though the names and dates of Central-American native kings have too little interest to general readers for traditions of them to be dwelt on here, they bring into view one important historical point, that the wondrous ruined cities of this region are not to be thought monuments of a perished race in a forgotten past, but that at least some of them belong to history, having been inhabited up to the conquest, apparently by the very nations who built them.

Turning now to the native chronicles of the Mexican nations, these are found to be substantial dated records going back to the 12th or 13th century, with some vague but not worthless recollections of national events from times some centuries earlier. These last-mentioned traditions, in some measure borne out by linguistic evidence of names of places, tribes, and persons, point to the immigration of detachments or branches of a widespread race speaking a common language, which is represented to us by the Aztec, still a spoken language in Mexico. This language was called *nahuatl*, and one who spoke it as his native tongue was called *nahuatlacatl*, so that modern anthropologists are following native precedent when they use the term *Nahua* for the whole series of peoples now under consideration.[1] Earliest of the Nahua nations, the Toltecs are traditionally related to have left their northern home of Huehuetlapallan in the 6th century; and, though this remote date cannot be treated as belonging to genuine history, there is other evidence of the real existence of the nation. Their name *Toltecatl* signifies an inhabitant of *Tollan*, "land of reeds," a place which, as has been already pointed out, appears elsewhere in the national traditions of this region, and has a definite geographical site in the present Tulan or Tula, north of the valley of Anahuac, where a Toltec kingdom of some extent seems to have had its centre. To this nation is ascribed not only the oldest but the highest culture of the Nahua nations; to them was due the introduction of maize and cotton into Mexico, the skilful workmanship in gold and silver, the art of building on a scale of vastness still witnessed to by the mound of Cholula, said to be Toltec work; the Mexican hieroglyphic writing and calendar are also declared to have been of Toltec origin. With the Toltecs is associated the mysterious tradition of Quetzalcoatl, a name which presents itself in Mexican religion as that of a great deity, god of the air, and in legend as that of a saintly ruler and civilizer. His brown and beardless worshippers describe him as of another race, a white man with noble features, long black hair and full beard, dressed in flowing robes. He came from Tullan

[1] It should be noticed that this word is not etymologically connected with the somewhat similar word *Anahuac*, of which the meaning is given at page 206.

or from Yucatan (for the stories differ widely), and dwelt twenty years among them, teaching men to follow his austere and virtuous life, to hate all violence and war, to sacrifice no men or beasts on the altars, but to give mild offerings of bread and flowers and perfumes, and to do penance by the votaries drawing blood with thorns from their own bodies. Legend tells stories of his teaching men picture-writing and the calendar, and also the artistic work of the silversmith, for which Cholula was long famed; but at last he departed, some say towards the unknown land of Tlapallan, but others to Coatzacualco on the Atlantic coast on the confines of Central America, where native tradition still keeps up the divine names of Gucumatz among the Quichés (see p. 208) and Cukulcan among the Mayas, these names having the same meaning as Quetzalcoatl in Aztec, viz., "Feathered Serpent." Native tradition held that when Quetzalcoatl reached the Atlantic he sent back his companions to tell the Cholulans that in a future age his brethren, white men and bearded like himself, should land there from the sea where the sun rises, and come to rule the country. That there is a basis of reality in the Toltec traditions is shown by the word *toltecatl* having become among the later Aztecs a substantive signifying an artist or skilled craftsman. It is further related by the Mexican historians that the Toltec nation all but perished in the 11th century by years of drought, famine, and pestilence, a few only of the survivors remaining in the land, while the rest migrated into Yucatan and Guatemala, where, as has been already pointed out, their name is commemorated in local records. After the Toltecs came the Chichimecs, whose name, derived from *chichi*, "dog," is applied to many rude tribes; the Chichimecs here in question are said to have come from Amaquemecan under a king named Xolotl, names which being Aztec imply that the nation was Nahua; at any rate they appear afterwards as fusing with more cultured Nahua nations in the neighbourhood of Tezcuco. Lastly is recorded the Mexican immigration of the seven nations, Xochimilca, Chalca, Tepaneca, Acolhua, Tlahuica, Tlascalteca, Azteca. This classification of the Nahuatlac tribes has a meaning and value. It is true that Aztlan, the land whence the Aztecs traced their name and source, cannot be identified by geographers, while the story of the separation of the seven nations at the place called Chicomoztoc or Seven Caves looks like national legend rather than real history. But the later stages of the long Aztec migration seem historical, and the map of Mexico still shows the names of several settlements recorded in the curious migration-map published by Gemelli Careri (*Giro del Mondo*, Venice, 1728) and commented on by Humboldt; among these local names are Tzompanco, "place of skulls," now Zumpango in the north of the Mexican valley, and Chapultepec, "grasshopper hill," now a suburb of the city of Mexico itself, where the Aztecs are recorded to have celebrated in 1195 the festival of tying up the "bundle of years" and beginning a new cycle. The Aztecs moving from place to place in Anahuac found little welcome from the Nahua peoples already settled there, whose own history was indeed one of incessant jealousy and quarrel. One of the first clear events of the Aztec arrival is their being made tributary by the Tepanecs, in whose service or alliance they began to manifest their warlike prowess in the fight near Tepeyacac, where now stands the famous shrine of Our Lady of Guadalupe. Thus they overcame in arms the Acolhuas, their superiors in civilization, who had made Tezcuco a centre of prosperity and improvement. By the 13th century the Aztecs by their ferocity had banded their neighbours together against them; some were driven to take refuge on the reedy lake shore at Acoculco, while others were taken as captives into Culhuacan. The king of this district was Coxcoxtli, whose name has gained an undeserved reputation even in Europe as "Coxcox, the Mexican Noah," from a scene in the native picture-writing where his name appears together with the figure of a man floating in a dug-out tree, which has been mistaken even by Humboldt for a representation of the Mexican deluge-myth. Coxcoxtli used the help of the Aztecs against the Xochimilco people, but his own nation, horrified at their bloodthirsty sacrifice of prisoners, drove them out to live for years in want and misery on the islands and swamps of the great salt lagoon, where they are said to have taken to making their *chinampas* or floating gardens of mud heaped on rafts of reeds and brush, which in later times were so remarkable a feature of Mexico. As one of the Aztec chiefs at the time of the founding of their city was called Tenoch, *i.e.*, "Stone-cactus," it is likely that from him was derived the name Tenochtitlan or "Stone-cactus place." Written as this name is in pictures or rebus, it probably suggested the invention of the well-known legend of a prophecy that the war-god's temple should be built where a prickly pear was found growing on a rock, and perched on it an eagle holding a serpent; this legend is still commemorated on the coins of Mexico. Mexico-Tenochtitlan, founded about 1325, for many years afterwards probably remained a cluster of huts, and the higher civilization of the country was still to be found among the other nations, especially among the Acolhuas in Tezcuco. The wars of this nation with the Tepanecs, which went on into the 15th century, were merely destructive, but larger effects arose from the expeditions under the Culhua king Acamapichtli, where the Aztec warriors were prominent, and which extended far outside the valley of Anahuac. Especially a foray southward to Quauhnahuac, now Cuernavaca, on the watershed between the Atlantic and Pacific, caused the bringing of goldsmiths and other craftsmen home to Tenochtitlan, which now began to rise in arts, the Aztecs laying aside their rude garments of aloe-fibre for more costly clothing, and going out as traders for foreign merchandise. In the 14th century the last great national struggle took place. The Acolhuas had at first the advantage, but Ixtlilxochitl did not follow up the beaten Aztecs but allowed them to make peace, whereupon, under professions of submission, they fell upon and sacked the city of Tezcuco. The next king of Tezcuco, Nezahualcoyotl, turned the course of war, when Azcapuzalco, the Tepanec stronghold, was taken and the inhabitants sold as slaves by the conquering Acolhuas and Aztecs; the place thus degraded became afterwards the great slave-market of Mexico. In this war we first meet with the Aztec name Moteuczoma, afterwards so famous in its Spanish form Montezuma. About 1430 took place the triple alliance of the Acolhua, Aztec, and Tepanec kings, whose capitals were Tezcuco, Mexico, and Tlacopan, the latter standing much below the other two. In fact the Aztecs now became so predominant that the rest of native history may be fairly called the Aztec period, notwithstanding the picturesque magnificence and intellectual culture which made Tezcuco celebrated under Nezahualcoyotl and his son Nezahualpilli. When the first Moteuczoma was crowned king of the Aztecs, the Mexican sway extended far beyond the valley plateau of its origin, and the gods of conquered nations around had their shrines set up in Tenochtitlan in manifest inferiority to the temple of Huitzilopochtli, the war-god of the Aztec conquerors. The rich region of Quauhnahuac became tributary; the Miztec country was invaded southward to the Pacific, and the Xicalanca region to what is now Vera Cruz. It was not merely for conquest and tribute that the fierce Mexicans ravaged the neighbour-lands, but they had a stronger motive than either in the desire to obtain multitudes of prisoners whose hearts were to be torn out

by the sacrificing priests to propitiate a pantheon of gods who well personified their bloodthirsty worshippers. The desire for war-captives as acceptable victims is related to have brought about an almost incredible agreement among nations of the Mexican alliance, that they should from time to time fight battles among themselves in order to provide prisoners for the altars. Thus there was something of the character of a religious war in the expedition made in 1469 under Axayacatl as far down the isthmus as Tehuantepec, whence the Mexican army came back with loads of rich plunder and thousands of captives, and the later ravaging of the Totonac region as far as the Atlantic, when the inhabitants were taken for sacrifice and their land recolonized by Aztecs. Ahuitzotl left the Aztec empire (as it is often somewhat ambitiously called) at the height of apparent power, but the cruel oppression of the subject regions had made their life almost unbearable, and the second Moteuczoma, coming to a rule already liable to break up from within, weakened it still more by upholding the class of chiefs or nobles against the common people who as warriors and traders had in great measure made the prosperity of the allied nations. The Mexicans had long tried to subjugate the stubborn little nation of Tlaxcallan (Tlascala), which had obstinately held out, though so hemmed in that for years the people lived without salt, this being no longer to be had from the sea-coast. Moteuczoma made a last effort to crush them, but in vain, and when the Spaniards came they were there as ready-made allies planted on the high road to Mexico. From the date when the festival of the new cycle was first celebrated in Chapultepec six 52-year periods had passed when in 1507 the new fire symbolizing the beginning of a new cycle was kindled for the last time on the breast of a human victim. Rumours of the coming of the Europeans may have before this date spread from Cuba, but in 1517 Cordova touched in Yucatan, and in 1518 Grijalva was on the east coast of Mexico, and the Aztecs first met the white men, in whom they saw, partly with hope and partly with fear, the fulfilment of the prophecy that Quetzalcoatl should one day return. With the Spanish conquest under Hernando Cortes (see CORTES) the native history of Mexico comes to an end.

CIVILIZATION.

Government. While the prairie tribes of America lived under the loose sway of chiefs and councils of old men, the settled nations of Mexico had attained to a somewhat highly organized government. This may be seen by the elaborate balance of power maintained in the federation of Mexico, Tezcuco, and Tlacopan, where each king was absolute in his own country, but in war or other public interests they acted jointly, with powers in something like the proportion in which they divided conquered lands and spoil, which was two-fifths each to Mexico and Tezcuco and one-fifth to Tlacopan. The successor of the Aztec king was customarily a chosen brother or nephew, the eldest having the first claim unless set aside as incompetent, and having to be a tried warrior; this mode of succession, which has been looked on as an elaborate practical device for securing practical advantages, seems rather to have arisen out of the law of choice among the descendants of the female line, found in American tribes of much lower culture. Something like this appears in the succession of kings of Tezcuco and Tlacopan, which went to sons by the principal wife, who was usually of the Aztec royal family. The Mexican chronicles, however, show instances of the king's son succeeding, or of powerful chiefs being elected to the kingship. The term republic is sometimes used to describe the little state of Tlascala, but this was in fact a federation of four chiefs, with an assembly of nobles. In the Zapotec district the Wiyatao or high-priest of Zopaa was a divine ruler before whom all prostrated themselves with faces to the ground; he was even too sacred to allow his foot to touch the earth, and was only seen carried in a litter.

Palaces, &c. The accounts given by the Spanish and native Mexican writers of the courts and palaces of the native kings must be taken with some reserve, from the tendency to use descriptive terms not actually untrue, but which convey erroneous ideas taken from European architecture; thus what are called columns of porphyry and jasper supporting marble balconies might perhaps be better described as piers carrying slabs, while the apartments and terraces must have been more remarkable for number and extent than architectural grandeur, being but low one-storied buildings. The principal palace of Mexico consisted of hundreds of rooms and halls ranged round three open squares, with women's apartments, granaries, storehouses, menageries, aviaries, of such extent that one of the companions of Cortes records having four times wandered about till he was tired, without seeing the whole. Not less remarkable was the palace of Tezcuco, surrounded with its groves and pleasure-gardens; and, though now hardly anything remains of the buildings above ground, the neighbouring hill of Tezcotzinco still has its stone steps and terraces; and the immense embankment carrying the aqueduct-channel of hewn stone which supplied water to basins cut in the solid rock still remains to prove that the chroniclers' descriptions, if highly-coloured, were at any rate genuine. Till the last century the gigantic figures of Axayacatl and his son Montezuma were to be seen carved in the porphyry hill of Chapultepec, but these as well as the hanging gardens have been destroyed, and only the groves of *ahuehuete* (cypress) remain of the ancient beauties of the place. That in the palace gardens flowers from the tierra caliente were transplanted, and water-fowl bred near fresh and salt pools fit for each kind, that all kinds of birds and beasts were kept in well-appointed zoological gardens where there were homes even for alligators and snakes,—all this testifies, not merely to barbaric ostentation, but to a cultivation of natural history which was really beyond the European level of the time. From the palaces and retinues of thousands of servants attached to the royal service may be inferred at once the despotic power of the Mexican rulers and the heavy taxation of the people; in fact some of the most remarkable of the picture-writings are tribute-rolls enumerating by hundreds and thousands the mantles, ocelot-skins, bags of gold-dust, bronze hatchets, loads of chocolate, &c., furnished periodically by the towns. Below the king was a numerous and powerful class of nobles, the highest of whom (*tlatoani*) were great vassals owing little more than homage and tribute to their feudal lord, while the natural result of the unruliness of the noble class was that the king to keep them in check increased their numbers, brought them to the capital as councillors, and balanced their influence by military and household officers, and by a rich and powerful merchant class. The nobles not only had privileges of rank and dignity, but substantial power over the plebeian or peasant class (*macehualli*), who submitted to much the same oppression and extortion at their hands as was customary in the Old World. The tenures of land in Mexico were those generally appearing in barbaric countries where invasion and military despotism have encroached on but not totally superseded the earlier tribal laws. The greatest estates belonged to the king, or had been granted to military chiefs whose sons succeeded them, or were the endowments of temples, but the *calpulli* or village community still survived, and each freeman of the tribe held and tilled his portion of the common lands. Below the freemen were the slaves, who were war-captives, persons enslaved for punishment, or children sold by their parents. Prisoners of war were mostly doomed to sacrifice, but other classes of slaves were mildly treated, retaining civil rights, and their children were born free.

The superior courts of law formed part of the palace, and there were tribunals in the principal cities, over each of which presided a supreme judge or *cihuacoatl*, who was irremovable, and whose criminal decisions not even the king might reverse; he appointed the lower judges and heard appeals from them; it is doubtful whether he judged in civil cases, but both kinds of suits were heard in the court below, by the *tlacatecatl* and his two associates, below whom were the ward-magistrates. Lands were set apart for the maintenance of the judges, and indeed nothing gives a higher idea of the elaborate civilization of Mexico than this judicial system, which culminated in a general court and council of state presided over by the king. The laws and records of suits were set down in picture-writings, of which some are still to be seen; sentence of death was recorded by drawing a line with an arrow across the portrait of the condemned, and the chroniclers describe the barbaric solemnity with which the king passed sentence sitting on a golden and jewelled throne in the divine tribunal, with one hand on an ornamented skull and the golden arrow in the other. Among the resemblances to Old-World law was the use of a judicial oath, the witness touching the ground with his finger and putting it to his lips, thus swearing by Mother Earth. The criminal laws were of extreme severity, even petty theft being punished by the thief being enslaved to the person he had robbed, while to steal a tobacco pouch or twenty ears of corn was death; he who pilfered in the market was then and there beaten to death, and he who insulted Xipe, the god of the gold- and silver-smiths, by stealing his precious metal, was skinned alive and sacrificed to the offended deity. Though aloe-beer or "pulque" was allowed for feasts and to invalids in moderation, and old people over seventy seem to be represented in one of the picture-writings as having liberty of drunkenness, young men found drunk were clubbed to death and young women stoned. Such a Draconian standard prevailing, it is hardly needful to enumerate the special penalties of such offences as witchcraft, fraud, removing landmarks, adultery, &c., which differed as to Justice.

whether the criminal had his heart cut out on the altar, his head crushed between two stones, &c.; while even lesser punishments were harsh, such as that of slanderers, whose hair was singed with a pine-torch to the scalp.

War. Based on conquest as the Aztec kingdom was, and with the craving for warlike glory fostered by the most bloodthirsty religion the world ever saw, it follows that the nation was above all other pursuits organized as a fighting community. To be a tried soldier was the road to honour and office, and the king could not be enthroned till he had with his own hand taken captives to be butchered on the war-god's altar at his coronation. The common soldiers were promoted for acts of daring, and the children of chiefs were regularly trained to war, and initiated by being sent into battle with veterans, with whose aid the youth took his first prisoner, but his future rise depended on how many captives he took unaided in fight with warlike enemies; by such feats he gained the dignity of wearing coloured blankets, tassels, and lip-jewels, and reached such military titles as that of "guiding eagle." The Mexican military costumes are to be seen in the picture-writings, where the military orders of princes, eagles, and tigers are known by their braided hair, eagles' beaks, and spotted armour. The common soldiers went into battle brilliant in savage war-paint, but those of higher rank had helmets like birds and beasts of prey, armour of gold and silver, wooden greaves, and especially the *ichcapilli*, the quilted cotton tunic two fingers thick, so serviceable as a protection from arrows that the Spanish invaders were glad to adopt it. The archers shot well and with strong bows, though their arrows were generally tipped only with stone or bone; their shields or targets, mostly round, were of ordinary barbaric forms; the spears or javelins had heads of obsidian or bronze, and were sometimes hurled with a spear-thrower or *atlatl*, of which pictures and specimens still exist, showing it to be similar in principle to those used by the Australians and Eskimo. The most characteristic weapon of the Mexicans was the *maquahuitl* or "hand-wood," a club set with two rows of large sharp obsidian flakes, a well-directed blow with which would cut down man or horse. These two last-mentioned weapons have the look of highly-developed savage forms, while on the other hand the military organization was in some respects equal to that of an Asiatic nation, with its regular companies commanded each by its captain and provided with its standard. The armies were very large, an expedition often consisting of several divisions each numbering eight thousand men, but the tactics of the commanders were quite rudimentary, consisting merely of attack by arrows and javelins at a distance, gradually closing into a hand-to-hand fight with clubs and spears, with an occasional feigned retreat to draw the enemy into an ambuscade. Fortification was well understood, as may still be seen in the remains of walled and escarped strongholds on hills and in steep ravines, while lagoon-cities like Mexico had the water approaches defended by fleets of boats, and the causeways protected by towers and ditches; even after the town was entered, the pyramid-temples with their surrounding walls were forts capable of stubborn resistance. It was held unrighteous to invade another nation without a solemn embassy to warn their chiefs of the miseries to which they exposed themselves by refusing the submission demanded, and this again was followed by a declaration of war, but in Mexico as in other more cultured countries this act of national morality degenerated into a ceremonial farce, where tribute was claimed from some neighbouring nation, or an Aztec god was offered to be worshipped in their temples, in order to pick a quarrel as a pretext for an invasion already planned to satisfy the soldiers with lands and plunder, and to meet the priests' incessant demands for more human sacrifices.

Among the accounts of the Mexican religion are some passages referring to the belief in a supreme deity. The word *teotl*, god, has been thought in some cases to bear this signification, but its meaning is that of deity in general, and it is applied not only to the sun-god but to very inferior gods. It is related that Nezahualcoyotl, the poet-king of Tezcuco, built a nine-storied temple with a starry roof above, in honour of the invisible deity called Tloquenahuaque, "he who is all in himself," or Ipalnemoan, "he by whom we live," who had no image, and was propitiated, not by bloody sacrifices, but by incense and flowers. Those who adopt the opinion of Asiatic admixture in Mexican culture will use it to account for this remarkable religious phenomenon, less easily accounted for by native development, while also the appearance of a rival deity of evil, bearing the name of Tlacatecolotl, or "man-owl," is mysterious. These divinities, however, seem to have had little or no place in the popular faith, which was occupied by polytheistic gods of more ordinary barbaric type. Tezcatlipoca was held to be the highest of these, and at the festival of all the gods his footsteps were expected to appear in the flour strewn to receive this sign of their coming. He was plainly an ancient deity of the race, for attributes of many kinds are crowded together in him, and he was prayed to in interminable formulas for help in war and for health and fortune, to deliver the nation from a wicked king, or to give pardon and strength to the penitent who had confessed his sins and been purified by washing. Between him and Quetzalcoatl, the ancient deity of Cholula, there had been old rivalry, as is related in legends of Quetzalcoatl coming into the land to teach men to till the soil, to work metals, and to rule a well-ordered state; the two gods played their famous match at the ball-game, and Tezcatlipoca, in the guise of a hoary-headed sorcerer, persuaded the sick and weary Quetzalcoatl to drink the magic pulque that sent him roaming to the distant ocean, where he embarked in his boat and disappeared from among men. These deities are not easily analysed, but on the other hand Tonatiuh and Metztli, the sun and moon, stand out in the distinctest personality as nature gods, and the traveller still sees in the huge adobe pyramids of Teotihuacan, with their sides oriented to the four quarters, an evidence of the importance of their worship. The war-god Huitzilopochtli, of whom one legend relates a supernatural conception in the ancient Tullan, while another story declares him to have been (like the Chinese war-god) a deified warrior-chief, was the real head of the Aztec pantheon; his idol remains in Mexico, a huge block of basalt on which is sculptured on the one side his hideous personage, adorned with the humming-bird feathers on the left hand which signify his name, while the not less frightful war-goddess Teoyaomiqui, or "divine-war-death," occupies the other side. Centeotl, the goddess of the all-nourishing maize, was patroness of the earth and mother of the gods, while Mictlanteuctli, lord of dead-land, ruled over the departed in the dim under-world. Numbers of lesser deities presided over classes of society, events, and occupations of life, such as Tlazolteotl, goddess of pleasure, worshipped by courtesans, Tezcatzoncatl, god of strong drink, whose garment in grim irony clothed the drunkard's corpse, and Xipe, patron of the goldsmiths. Below these were the usual crowd of nature-spirits of hills and groves, whose shrines were built by the roadside to receive offerings from passers-by. The temples were called *teocalli* or "god's house," and the teocallis of the greater deities rivalled in size as they resembled in form the temples of ancient Babylon. They were pyramids on a square or oblong base, rising in successive terraces to a small summit-platform. The great teocalli of Huitzilopochtli in the city of Mexico stood in an immense square, whence radiated the four principal thoroughfares, its courtyard being enclosed by a square, of which the stone wall, called the *coatepantli* or serpent-wall from its sculptured serpents, measured nearly a quarter of a mile on each side. In the centre, the oblong pyramid of rubble cased with hewn stone and cemented, 375 × 300 feet at the base, and rising steeply in five terraces to the height of 86 feet, showed conspicuously to the city the long processions of priests and victims winding along the terraces and up the corner flights of steps. On the paved platform were three-story tower temples in whose ground-floor stood the stone images and altars, and before that of the war-god the green stone of sacrifice, humped so as to bend upward the body of the victim that the priest might more easily slash open the breast with his obsidian knife, tear out the heart and hold it up before the god, while the captor and his friends were waiting below for the carcase to be tumbled down the steps for them to carry home to be cooked for the feast of victory. Before the shrines reeking with the stench of slaughter, the eternal fires were kept burning, and on the platform stood the huge drum covered with snakes' skin, whose fearful sound was heard for miles. From the terrace could be seen seventy or more other temples within the enclosure, with their images and blazing fires, and the *tzompantli* or "skull-place," where the skulls of victims by tens of thousands were skewered on cross-sticks or built into towers. There also might be seen the flat circular *temalacatl* or "spindle-stone," where captives armed with wooden weapons were allowed the mockery of a gladiatorial fight against well-armed champions. The great pyramid of Cholula with its hemispherical temple of Quetzalcoatl at the top, now an almost shapeless hill surmounted by a church, was about thrice as long and twice as high as the teocalli of Mexico. A large fraction of the Mexican population were set apart as priests or attendants to the services of the gods. The rites performed were such as are found elsewhere, prayer, sacrifice, processions, dances, chants, fasting and other austerities, but there are some peculiarities of detail. Prayers and other formulas have been copied down by Sahagun and other chroniclers, of endless prolixity, but not without occasional touches of pathos. The following are a few sentences from a prayer to Tezcatlipoca, interceding for the poor: "O our lord, protector most strong and compassionate, invisible and impalpable, thou art the giver of life; lord of all, and lord of battles, I present myself here before thee to say some few words concerning the need of the poor people, the people of none estate or intelligence. . . . Know, O Lord, that thy subjects and servants suffer a sore poverty, that cannot be told of more than that it is a sore poverty and desolateness. The men have no garments nor the women to cover themselves with, but only rags rent in every part that let the wind and cold in. . . . If they be merchants, they now sell only cakes of salt and broken pepper; the people that have something despise their wares, so that they go out to sell from door to door and from house to house; and when they sell nothing they sit down sadly by some fence or wall, or in some corner,

licking their lips and gnawing their nails for the hunger that is in them, they look on one side and the other at the mouths of those who pass by, hoping peradventure that one may speak some word to them. O compassionate God, the bed on which they lie is not a thing to rest upon, but to endure torment in; they draw a rag over them at night and so sleep. . . . O our Lord, in whose power it is to give all content, consolation, sweetness, softness, prosperity, and riches, for thou alone art lord of all good, have mercy upon them, for they are thy servants. . . . I supplicate thee that thou wilt lift up their heads with thy favour and aid, that thou wilt see good that they enjoy some days of prosperity and tranquillity, so that they may sleep and know repose, having prosperous and peaceable days of life. . . . Should this nation, for whom I pray and entreat thee to do them good, not understand what thou hast given, thou canst take away the good and pour out cursing, so that all evil may come upon them, and they become poor, in need, maimed, lame, blind, and deaf; then indeed they shall waken and know the good that they had and have not, and they shall call upon thee and lean toward thee; but thou will not listen, for in the day of abundance they would not understand thy goodness towards them." These prayers seem essentially genuine; indeed there was no European model from which they could have been imitated; but at the same time it must be remembered that they come down in Spanish writing, and not untouched by Spanish influence, as in one passage where there is a mention of sheep, an animal of course unknown to the native Mexicans. As to sacrifice, maize and other vegetables were offered, and occasionally rabbits, quails, &c.; but, in the absence of cattle, human sacrifice was the chief rite, and cannibalism prevailed at the feasts. Incense was constantly used, especially the *copalli* (copal) well known to us for varnish; little terra-cotta censers are among the commonest of Mexican antiquities. Long and severe religious fasts were customary at special seasons, and drawing blood from the arms, legs, and body, by thrusting in aloe thorns, and passing sharp sticks through the tongue, was an habitual act of devotion recalling the similar practices of devotees in India. The calendar of religious festivals for the whole course of the Mexican year has been preserved. Each 20-day period had one or more such celebrations. In the month of the "diminishing of waters" the rain-gods or Tlalocs were propitiated by a procession of priests with music of flutes and trumpets carrying on plumed litters infants with painted faces, in gay clothing with coloured paper wings, to be sacrificed on the mountains or in a whirlpool in the lake. It is said that the people wept as they passed by; but if so this may have been a customary formality, for the religion of these nations must have quenched all human sympathy. In the next month the god Xipe-totec, already mentioned, had his festival called the "flaying of men" from the human victims being flayed, after their hearts were torn out, for young men to dress in their skins and perform dances and sham fights. The succeeding festival of Camaxtli was marked by a severe fast of the priests, after which stone knives were prepared with which a hole was cut through the tongue of each, and numbers of sticks passed through. For the great festival of Tezcatlipoca, the handsomest and noblest of the captives of the year had been chosen as the incarnate representative of the god, and paraded the streets for public adoration dressed in an embroidered mantle with feathers and garlands on his head and a retinue like a king; for the last month they married him to four girls representing four goddesses; on the last day wives and pages escorted him to the little temple of Tlacochcalco, where he mounted the stairs, breaking an earthenware flute against each step; this was a symbolic farewell to the joys of the world, for as he reached the top he was seized by the priests, his heart torn out and held up to the sun, his head spitted on the tzompantli, and his body eaten as sacred food, the people drawing from his fate the moral lesson that riches and pleasure may turn into poverty and sorrow. The manner of the victim's death in these festivals afforded scope for variety; they dressed them and made them dance in character, threw them into the fire for the fire-god, or crushed them between two balanced stones at the harvest-festival. The ordinary pleasures of festivals were mingled with all this, such as dances in beast-masks, sham fights, and children's games, but the type of a religious function was a sickening butchery followed by a cannibal feast.

Picture-writing. The Mexican priesthood, being the educated class, were much concerned with the art of picture-writing, which they had developed to a stage quite above the rude figures of the American hunting-tribes, and used systematically as a means of recording religious festivals and legends, as well as keeping calendars of years and recording the historical events which occurred in them. Facsimiles of several of these interesting documents, with their translations, may be seen in Kingsborough. On inspecting these it will be seen that their main principle is pictorial. Gods are represented with their appropriate attributes,—the fire-god hurling his spear, the moon-goddess with a shell, &c.; the scenes of human life are pictures of warriors fighting with club and spear, men paddling in canoes, women spinning and weaving, &c. An important step towards phonetic writing appears, however, in the picture-names of places and persons. The simplest forms of these depict the objects signified by the name, as where *Chapultepec* or "grasshopper-hill" is represented by a grasshopper on a hill, or a stone with a cactus on it stands for *Tenoch* or "stone-cactus," the founder of *Tenochtitlan*. The system had, however, risen a stage beyond this when objects were drawn to represent, not themselves, but the syllables forming their names, as where a trap, an eagle, a pricker, and a hand are put together not to represent these objects, but in order that the syllables of their names *mo-quauh-zo-ma* should spell the word Moquauhzoma (see Aubin's introduction to Brasseur, *Hist. du Mexique*, vol. i. p. lxviii.). The analogy of this to the manner in which the Egyptian hieroglyphs passed into phonetic signs is remarkable, and writing might have been invented anew in Mexico had it not been for the Spanish conquest. The Aztec numerals, which were vigesimal or reckoned by scores, were depicted by dots or circles up to 20, which was represented by a flag, 400 (a score of scores) by a feather, and 8000 (a score of scores of scores) by a purse; but for convenience these symbols might be halved and quartered, so that 534 might be shown by one feather, one quarter of a feather, one flag, one-half of a flag, and four dots. The Mexican calendar depended on the combination of numbers with picture-signs, of which the four principal were the rabbit, reed, flint, house—*tochtli, acatl, tecpatl, calli.* The cycle of 52 years was reckoned by combining these signs in rotation with numbers up to 13, thus:—1 rabbit, 2 reed, 3 flint, 4 house, 5 rabbit, 6 reed, &c. By accident this calendar may be exactly illustrated with a modern pack of cards laid out in rotation of the four suits, as, ace of hearts, 2 of spades, 3 of diamonds, 4 of clubs, 5 of hearts, 6 of spades, &c. In the Mexican ritual calendar of the days of the year, the same method is carried further, the series of twenty day-signs being combined in rotation with numbers up to 13; as this cycle of days only reaches 260, a series of nine other signs are affixed in addition, to make up the 365-day year. It is plain that this rotation of signs served no useful purpose whatever, being less convenient than ordinary counting such as the Mexicans employed in their other calendar already mentioned, where the 20-day periods had each a name like our months, and their days had signs in regular order. Its historical interest depends on its resemblance to the calendar-system of central and eastern Asia, where among Mongols, Tibetans, Chinese, &c., series of signs are thus combined to reckon years, months, and days; for instance, the Mongol cycle of 60 years is recorded by the zodiac or series of 12 signs—mouse, bull, tiger, &c., combined in rotation with the five male and female elements—fire, earth, iron, water, wood; as "male-fire-bull" year, &c. This comparison is worked out in Humboldt's *Vues des Cordillères*, as evidence of Mexican civilization being borrowed from Asia. Naturally the Mexican calendar-system lent itself to magic in the same way as the similar zodiac-signs of the Old World, each person's fate being affected by the qualities of the signs he was born under, and the astrologer-priests being called in to advise on every event of life. Of all Mexican festivals the most solemn was that of the *xiuhmolpilli*, or "year-binding," when the 52-year cycle or bundle of years came to an end. It was believed that the destruction of the world, which after the Hindu manner the Mexicans held to have already taken place three or four times, would happen again at the end of a cycle. As the time drew near, the anxious population cleansed their houses and put out all fire, and on the last day after sunset the priests, dressed in the garb of gods, set out in procession for the hill of Huixachtla, there to watch for the approach of the Pleiades to the zenith, which gave the auspicious signal for the lighting of the new fire. The finest of the captives was thrown down and fire kindled on his breast by the wooden drill of the priest; then the victim's heart was torn out, and his body flung on the pile kindled with the new flame. The people watching from their flat housetops all the country round saw with joy the flame on the sacred hill, and hailed it with a thank-offering of drops of blood drawn from their ears with sharp stone-flakes. Swift runners carried burning brands to rekindle the fires of the land, the sacred fire on the teocalli of the war-god blazed up again, and the people began with feasting and rejoicing the new cycle.

Education. Mexican education, at any rate that of the upper class, was a systematic discipline much under the control of religion, which here presents itself under a more favourable light. After the birth of a child, the *tonalpouhqui* or "sun-calculator" drew its horoscope from the signs it was born under, and fixed the time for its solemn lustration or baptism, performed by the nurse with appropriate prayers to the gods, when a toy shield and bow were provided if it was a boy, or a toy spindle and distaff if it was a girl, and the child received its name. An interesting picture-writing, to be seen in Kingsborough, shows the details of the boy's and girl's education, from the early time when three small circles over the child show it to be three years old, and a drawing of half a tortilla or corn-cake shows its allowance for each meal; as they grow older the lads are seen beginning to carry burdens, paddle the canoe, and fish, while the girls learn to spin and weave, grind maize, and cook,—good conduct being enforced by punishments of increasing severity, up to pricking their bodies with aloe-thorns and holding

their faces over burning chillis. The schools were extensive buildings attached to the temples, where from an early age boys and girls were taught by the priests to sweep the sanctuaries and keep up the sacred fires, to fast at proper seasons and draw blood for penance, and where they received moral teaching in long and verbose formulas. Those fit for a soldier's life were trained to the use of weapons and sent early to learn the hardships of war; children of craftsmen were usually taught by their fathers to follow their trade; and for the children of nobles there was elaborate instruction in history, picture-writing, astrology, religious doctrines, and laws. Marriages depended much, as they do still in the East, on comparison of the horoscopes of the pair to ascertain if their birth-signs were compatible. Old women were employed as go-betweens, and the marriage ceremony was conducted by a priest who after moral exhortations united the young couple by tying their garments together in a knot, after which they walked seven times round the fire, casting incense into it; after the performance of the marriage ceremony the pair entered together on a four days' fast and penance before the marriage was completed. The funeral rites of the Mexicans are best seen in the ceremonies at the death of a king. The corpse laid out in state was provided by the priest with a jug of water for his journey, and with bunches of cut papers to pass him safely through each danger of the road—the place where the two mountains strike together, the road guarded by the great snake and the great alligator, the eight deserts and the eight hills; they gave him garments to protect him from the cutting wind, and buried a little dog by his side to carry him across the nine waters. Then the royal body was invested in the mantles of his patron-gods, especially that of the war-god, for Mexican kings were warriors; on his face was placed a mask of turquoise mosaic, and a green chalchihuite-stone as a heart between his lips. In older times the dead king was buried on a throne with his property and dead attendants round him. But after cremation came in a mourning procession of servants and chiefs carried the body to the funeral pyre to be burnt by the demon-dressed priests, after which the crowd of wives and slaves were exhorted to serve their lord faithfully in the next world, were sacrificed and their bodies burnt. Common people would not thus be provided with a ghostly retinue, but their simpler funeral ceremonies were as far as they went similar to those of their monarch.

The staple food of the Mexicans before the conquest has continued with comparatively little change among the native race, and has even been adopted by those of European blood. Maize or Indian corn was cultivated on patches of ground where, as in the Hindu *jûm*, the trees and bushes were burnt and the seed planted in the soil manured by the ashes. A sharp-pointed planting stick, a wooden shovel, and a bronze-bladed hoe called a *coatl* were the simple implements. The Mexicans understood digging channels for irrigation, especially for the cultivation of the *cacahuatl*, from which they taught the Europeans to prepare the beverage *chocollatl*; these native names passed into English as the words cacao, or cocoa, and chocolate. Other vegetables adopted from Mexico are the tomata (*tomatl*) and the *chilli*, used as flavouring to native dishes. The maize was ground with a stone roller on the grinding stone or *metlatl*, still known over Spanish America as the *metate*, and the meal baked into thin oval cakes called by Aztecs *tlaxcalli*, and by Spaniards *tortilla*, which resemble the *chapati* of India and the oat-cake of Scotland. The Mexicans were also skilful makers of earthen pots, in which were cooked the native beans called by the Spanish *frijoles*, and the various savoury stews still in vogue. The juice extracted by tapping the great aloe before flowering was fermented into an intoxicating drink about the strength of beer, *octli*, by the Spaniards called *pulque*. Tobacco, smoked in leaves or cane-pipes or taken as snuff, was in use, especially at feasts. It is related that in old times Mexican clothing was of skins or woven aloe and palm fibre, but at the time of the conquest cotton was largely cultivated in the hot lands, spun with a spindle, and woven in a rudimentary loom without a shuttle into the mantles and breech-cloths of the men and the chemises and skirts of the women, garments often of fine texture and embroidered in colours. Ornaments of gold and silver, and jewels of polished quartz and green chalchihuite were worn,—not only the ears and nose but the lips being pierced for ornaments. The artificers in gold and silver melted the metals by means of a reed-blowpipe and cast them solid or hollow, and were also skilled in hammered work and chasing, as some fine specimens remain to show, though the famous animals modelled with gold and silver fur, feathers, and scales have disappeared. Iron was not known, but copper and tin ores were mined, and the metals combined into bronze of much the same alloy as in the Old World, of which hatchet blades and other instruments were made, though their use had not superseded that of obsidian and other sharp stone flakes for cutting, shaving, &c. Metals had passed into a currency for trading purposes, especially quills of gold-dust and T-shaped pieces of copper, while cocoa-beans furnished small change. The vast size of the market-squares with their surrounding porticos, and the importance of the caravans of merchants who traded with other nations, show that mercantile had risen into some proportion to military interests. Nor was the wealth and luxury of Mexico and surrounding regions without a corresponding development of art. The stone sculptures such as that remaining of Xochicalco, which is figured by Humboldt, as well as the ornamented woodwork, feather-mats, and vases, are not without artistic merit. The often-cited poems attributed to Nezahualcoyotl may not be quite genuine, but at any rate poetry had risen above the barbaric level, while the mention of ballads among the people, court odes, and the chants of temple choirs would indicate a vocal cultivation above that of the instrumental music of drums and horns, pipes and whistles, the latter often of pottery. Solemn and gay dances were frequent, and a sport called the bird-dance excited the admiration of foreigners for the skill and daring with which groups of performers dressed as birds let themselves down by ropes wound round the top of a high mast, so as to fly whirled in circles far above the ground. The ball-game of the Mexicans, called *tlachtli*, was, like tennis, the pastime of princes and nobles; special courts were built for it, and the ball of india-rubber (perhaps the first object in which Europeans became acquainted with this valuable material) might not be touched by the hands, but was driven against the walls by blows of the knee or elbow, shoulder or buttock. The favourite game of *patolli* has been already mentioned for its similarity to the *pachisi* of modern India.

Art and pastime.

Central-American culture.

The accounts given by Spanish writers of the Central Americans in their state after the Spanish conquest are very scanty in comparison with the voluminous descriptions of Aztec life. They bring out perfectly, however, the fact of close connexion between the two civilizations. Some Central-American peoples were actually Mexican in their language and culture, especially the Pipils of Guatemala and a large part of the population of Nicaragua, but these were descendants of Aztecs or allied peoples who in the comparatively modern times of Aztec power invaded and colonized these distant countries (see Buschmann, *Aztek. Ortsnamen*, viii., ix.). With regard to the Central-American nations proper, especially the Mayas of Yucatan and the Quichés of Guatemala, who dwelt in the cities and worshipped in the temples of Chichen-Itza and Uxmal, Palenque and Copan, the problem of Aztec connexion is deeper and obscurer. How closely related these nations were in institutions to the Mexicans appears, not only in their using the same peculiar weapons, such as the spear-thrower and the toothed club or maquahuitl, but in the similarity of their religious rites, such as drawing blood from their bodies as an act of penance, and sacrificing human victims by cutting open the breast and tearing out the heart; the connexion is evident in such special points as the ceremony of marriage by tying together the garments of the couple, or in holding an offender's face over burning chillis as a punishment; the native legends of Central America make mention of the royal ball-play, which was the same as the Mexican game of tlachtli already mentioned. At the same time many of the Central-American customs differed from the Mexican; thus in Yucatan we find the custom of the youths sleeping in a great bachelor's house, an arrangement common in various parts of the world, but not in Mexico; the same remark applies to the Maya exogamous law of a man not taking a wife of his own family name (see Diego de Landa, *Relacion de Yucatan*, ed. Brasseur de Bourbourg, p. 140), which does not correspond with Mexican custom. We have the means of comparing the personal appearance of the Mexicans and Central Americans by their portraits on early sculptures, vases, &c.; and, though there does not appear any clear distinction of race-type, the extraordinary back-sloping foreheads of such figures as those of the bas-reliefs of Palenque prove that the custom of flattening the skull in infancy prevailed in Central America to an extent quite beyond any such habit in Mexico. It is from the ruined cities now buried in the Central-American forests that we gain the best information as to the nations who built them. The notion sometimes propounded that these famous cities were of great antiquity and the work of extinct nations has no solid evidence; some of them may have been already abandoned before the conquest, but others were inhabited, and by the ancestors of the Indians who now build their mean huts and till their patches of maize round the relics of the grander life of their ancestors. In comparing these ruins through the districts of Yucatan, Chiapas, Guatemala, and Honduras, it is evident that, though they are not the work of a single nation, but of two or more highly distinct in language, yet these nations had the great bond of a common system of pictorial or written characters. One specimen of a Central-American inscription may give a general idea of them all, whether it be from the sculptured façade of a temple sketched by Catherwood, or from the painted deerskin called the Dresden Codex (reproduced in Kingsborough), or from the chapter of Diego de Landa where he professes to explain and translate the characters themselves. These consist of combinations of faces, circles, lines, &c., arranged in compartments in so complex a manner that hardly two are found alike. How they conveyed their meaning, how far they pictorially represented ideas or spelt words in the different languages of the country, is a question not yet answered in a complete way; Landa's description (p. 320) gives a table of a number of their elements as phonetically representing letters or syllables, but, though there may be a partial truth in his rules, they

are too insufficient or too erroneous to serve for any general decipherment. Most of what has been written on this enticing subject is worthless, but a promising attempt has been made by E. S. Holden, who has analysed the combined figures into their elementary lines (*First Annual Report of Bureau of Ethnology*, Smithsonian Institution, Washington, 1881; see also Charencey, *Mélanges de Philologie et de Paléographie Américaines*, Paris, 1883). One point as to the Central-American characters is clear, that part of them are calendar-signs recording dates. From the accounts given by Landa and other writers it is plain that the Central-American calendar, reckoning the year in twenty-eight periods of thirteen days, was the same in its principle of combining signs as that of Mexico here mentioned at page 212. The four leading Maya signs called *kan*, *muluc*, *ix*, *cauac* corresponded in their position to the four Aztec signs rabbit, reed, flint, house, but the meanings of the Maya signs are, unlike the Aztec, very obscure. A remarkable feature of the Central-American ruins is the frequency of truncated pyramids built of hewn stone, with flights of steps up to the temple built on the platform at top. The resemblance of these structures to the old descriptions and pictures of the Mexican teocallis is so striking that this name is habitually given to them. The teocallis built by the Nahua or Mexican nations have been mostly destroyed, but two remain at Huatusco and Tusapan (figured in Bancroft, vol. iv. pp. 443, 456), which bear a strong resemblance to those of Palenque. On the whole it is not too much to say that, in spite of differences in style, the best means of judging what the temples and palaces of Mexico were like is to be gained from the actual ruins in Central America. On the other hand, there are features in Central-American architecture which scarcely appear in Mexican. Thus at Uxmal there stands on a terraced mound the long narrow building known as the governor's house (Casa del Gobernador), 322 feet long, 39 feet wide, 26 feet high, built of rubble stone and mortar faced with square blocks of stone, the interior of the chambers rising into a sloping roof formed by courses of stonework gradually overlapping in a "false arch." The same construction is seen in the buildings forming the sides of a quadrangle and bearing the equally imaginary name of the nunnery (Casa de Monjas); the resemblance of the interior of one of its apartments to an Etruscan tomb has often been noticed (see Fergusson, *History of Architecture*, vol. i.; Viollet-le-Duc, in Charnay). Attempts to trace the architecture of Central America to direct derivation from Old-World types have not been successful, while on the other hand its decoration shows proof of original invention, especially in the imitations of woodwork which, as the above-mentioned architects have pointed out, passed into sculptured ornament when the material of construction became stone, instead of wood. Thus the architectural remains, though they fail actually to solve the historical problem of the high culture of the nations round the Gulf of Mexico, throw much light on it when their evidence is added to that of religion and customs. Whether Mexican civilization was a barbaric copy of that which flourished in the now deserted Central-American cities, or whether the nations who built these cities themselves raised to a higher level a civilization derived from Mexico, two things seem probable,—first, that the civilizations of Mexico and Central America were pervaded by a common influence in religion, art, and custom; second, that this common element shows traces of the importation of Asiatic ideas into America.

Among works of reference on the ancient history and civilization of Mexico and Central America may be mentioned H. H. Bancroft, *The Native Races of the Pacific States of North America*, London, 1875-6 (contains the most complete summary, with references to original authorities); Brasseur de Bourbourg, *Histoire des Nations Civilisées du Mexique et de l'Amérique-Centrale*, Paris, 1857-59 (a valuable collection of materials, but the author's own views are mostly fanciful); Prescott, *History of the Conquest of Mexico*; Clavigero, *Storia Antica del Messico*, Cesena, 1780 (contains the substance of earlier writers, such as Gomara, Torquemada, Acosta, Boturini, &c.). For special topics:—Lord Kingsborough, *Antiquities of Mexico*, London, 1831-48 (contains facsimiles and interpretations of picture-writings, the native chronicles of Ixtlilxochitl and Tezozomoc, a reprint of Sahagun, &c.); A. von Humboldt, *Vues des Cordillères, et Monumens des Peuples Indigènes de l'Amérique*, Paris, 1816 (Mexican civilization, picture-writing, calendar, &c.). Travels and descriptions of antiquities, &c.:—Dupaix (in Kingsborough); C. Nebel, *Viaje Pintoresco y Arqueológico sobre la República Mejicana*. Paris, 1839; F. de Waldeck, *Voyage Pittoresque et Archéologique dans la Province d Yucatan*, Paris, 1838, and *Palenqué et Autres Ruines*. Paris, 1866; D. Charnay, *Cités et Ruines Américaines*, avec texte par Viollet-le-Duc, Paris, 1863; J. L. Stephens, *Incidents of Travel in Central America*, &c., New York, 1841; *Incidents of Travel in Yucatan*, New York, 1858; Brantz Mayer, *Mexico*, New York, 1854; Tylor, *Anahuac, or Mexico and the Mexicans*, London, 1861, &c.

(E. B. T.)

Plate I.

II. THE REPUBLIC OF MEXICO.

Mexico, Aztec *Mexitli*.[1] (Estados Unidos de Mexico), is a federal republic in North America, bounded N. by the United States (California, Arizona, and New Mexico), E. by Texas and the Gulf of Mexico, S. by Guatemala and British Honduras, where the boundary lines are still partly undetermined, W. by the Pacific Ocean. Lying between 33° and 15° N. lat. and 87° and 117° W. long., Mexico stretches about 1950 miles north-north-west and south-south-east, with a mean breadth of 400 miles, varying from about 1000 in 26° N. to 130 at the narrowest part of the Tehuantepec isthmus. It has a coast-line of nearly 6000 miles,—about 4200 on the Pacific and 1600 on the Atlantic. The seaboard is little varied either by deep inlets, bold headlands, broad estuaries, or large islands. On the west side are the vast Gulf of California, in outline somewhat resembling the Red Sea, and so named by some of the early navigators, and the open Bay of Tehuantepec, besides the smaller inlets of Acapulco and San Blas, forming two of the finest harbours in the world, and almost the only safe ones in the republic. On the east side the coast is mostly beset by lagoons and sand-banks, with no good havens, Campéche, Vera Cruz, Tampico, and Matamoras being all little better than open roadsteads exposed to the fierce "nortes," or north-easterly gales, that sweep the Gulf of Mexico for a great part of the year. Of headlands the most prominent are Capes S. Lucas and Palmas at the south extremity of Lower California, Corrientes south from San Blas, and Catoche in the north-east of Yucatan. Besides this peninsula, which projects north-north-east, the only other is that of Lower California, which projects south-south-east parallel to the mainland. The islands are few in number, and all of insignificant size, the most noteworthy being Tiburon and Angel de la Guarda in the Gulf of California, the uninhabited Revillagigedo group in the Pacific, and Cozumel off the Yucatan coast. Mexico comprises altogether twenty-seven confederate states, one territory, and the Federal District, with areas, populations, and chief towns as under:[2]—

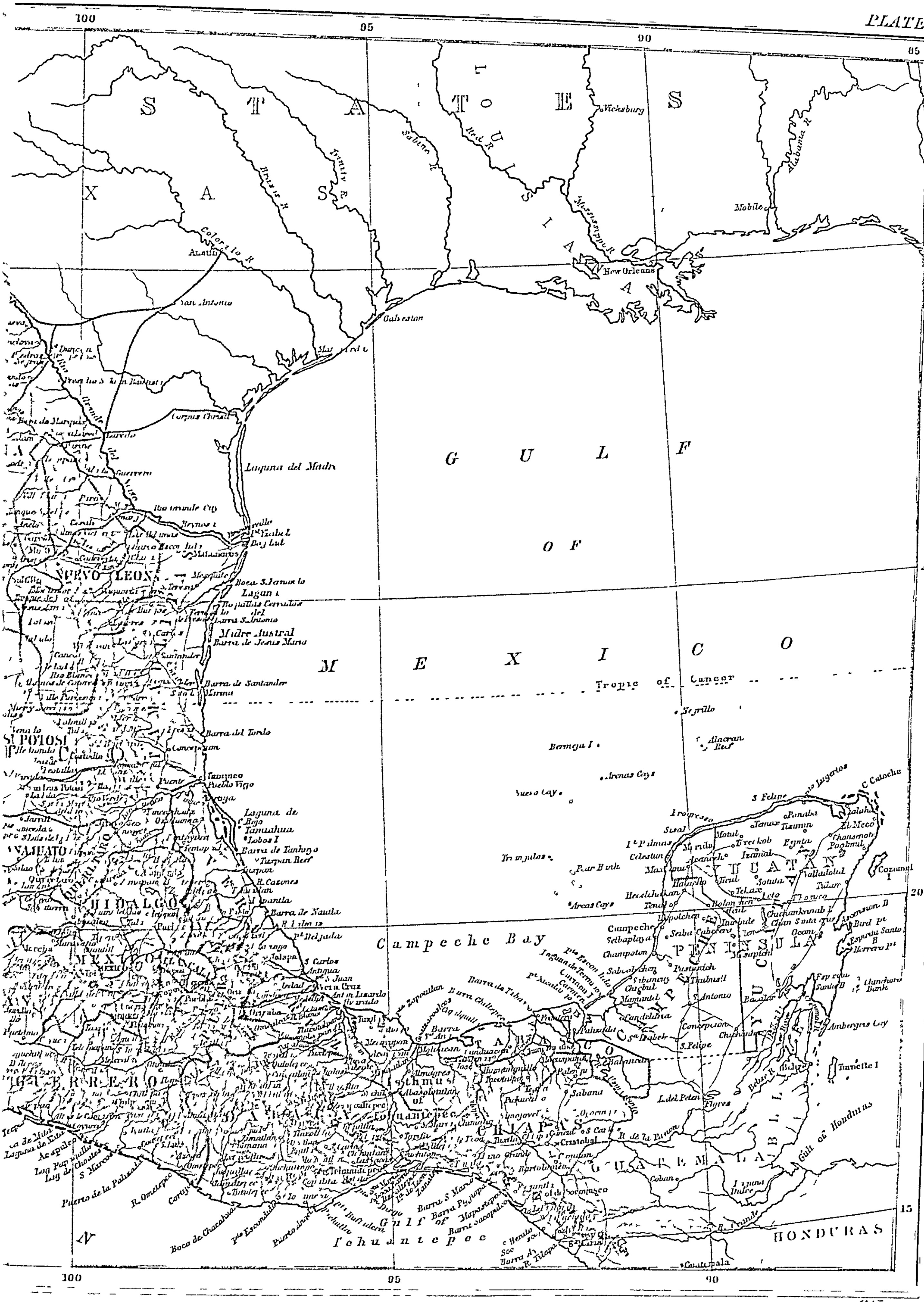
	States.	Area in Square Miles.	Population (1880).	Capital.	Population (1877-80).
Northern.	Sonora	81,022	139,140	Ures	9,700
	Chihuahua	105,295	180,758	Chihuahua	12,116
	Coahuila	61,050	104,131	Saltillo	11,340
	Nuevo-Leon	11,363	191,861	Monterey	15,300
Atlantic.	Tamaulipas	28,659	141,747	Ciudad Victoria	7,800
	Vera Cruz	27,433	504,970	Jalapa	12,400
	Tabasco	12,716	93,387	San Juan Bautista	6,800
	Campéche	26,083	86,299	Campéche	15,190
	Yucatan	32,658	285,384	Merida	32,000
Pacific.	Sinaloa	25,927	167,093	Culiacan	7,878
	Jalisco	48,967	994,900	Guadalajara	78,600
	Colima	2,394	65,827	Colima	23,572
	Michoacan	21,609	618,857	Morelia	20,400
	Guerrero	24,226	308,716	Bravos	3,800
	Oajaca	27,389	718,194	Oajaca	26,228
	Chiapas	16,769	219,735	San Cristobal	8,300
Central.	Durango	42,643	190,846	Durango	27,119
	Zacatecas	26,585	413,603	Zacatecas	32,000
	Aguas Calientes	2,216	140,430	Aguas Calientes	31,872
	San Luis Potosi	28,889	506,799	San Luis Potosi	34,300
	Guanajuato	11,130	788,202	Guanajuato	56,112
	Queretaro	3,429	179,915	Queretaro	27,560
	Hidalgo	8,480	434,096	Pachuca	12,500
	Mexico	9,598	696,038	Toluca	12,700
	Morelos	1,898	154,946	Cuernavaca	16,320
	Puebla	11,761	704,372	Puebla	64,588
	Tlaxcala	1,498	133,498	Tlaxcala	4,300
	Federal District	85	354,340	Mexico	241,110
	Lower California (Territory)	59,033	23,195	La Paz	2,396
		763,804	9,577,279		

Since the appearance of A. von Humboldt's classic work on *New Spain*, as Mexico was called in the colonial times, this region has continued to be regarded as forming a main link in the vast chain supposed to stretch across the entire length of the American continent from Cape Physical features. Plateaus and mountains.

[1] In this, as in all other Aztec names, the *x* (or *j*) represents the English sound *sh*; hence *Mexitli* and *Mexico* should be properly pronounced *Meshitli*, *Meshico*. But they do not appear to have ever been so pronounced by the Spaniards, who naturally gave to the *x* its ordinary Spanish sound of the German *ch*.

[2] These figures, in the absence of scientific surveys and a trustworthy census, are necessarily more or less approximate. The areas are those of Ripley and Dana, based on A. Garcia Cuba's *Carta geografica* (Mexico, 1874); the populations of the states and capitals are the estimates of Emiliano Busto in his *Estadistica de la Republica Mexicana* (Mexico, 1880). A writer in the *Times* of December 7, 1882, estimates the whole population at 12,000,000, much too high a figure.

Long. West of Greenwich



S T A T E S
T E X A S
L O U I S I A N A
Vicksburg
Red R
Sabine R
Trinity R
Brazos R
Colorado R
Mississippi R
Alabama R
Mobile
Austin
San Antonio
New Orleans
Galveston
Corpus Christi
Laguna del Madre
G U L F
O F
M E X I C O
Tropic of Cancer
Matamoros
Nuevo Leon
Madre Austral
Barra de Santander
Barra del Tordo
Tampico
Laguna de Tamiahua
Lobos I
Tuxpan Reef
Hidalgo
Jalapa
Vera Cruz
Bermeja I
Arenas Cays
Alacran Reef
Triangulos
Arcas Cay
Campeche Bay
Campeche
Carmen I
S Felipe
C Catoche
Progreso
Merida
Celestun
Sisal
Valladolid
Yucatan Peninsula
Cozumel I
Ascension B
Espiritu Santo B
Chinchorro Bank
Ambergris Cay
Turneffe I
Belize
Flores
L del Peten
Tabasco
Chiapas
Guerrero
Oaxaca
Isthmus of Tehuantepec
Gulf of Tehuantepec
Acapulco
Guatemala
Coban
Gulf of Honduras
Honduras
Cristobal
S Marcos
Puerto de la Paliza
Puerto Escondido
R Tilapa

flow through the profound rocky gorges or *barrancas*, as they are here called, which form a characteristic feature of the Mexican table-lands.[1] On the east side some of these barrancas, here running mostly west and east, attain depths of 800 to 1000 feet in the unfossiliferous limestones of that region; and even on the west coast the De Beltran cañon is flanked by sheer rocky walls over 500 feet high. Hence the rivers are almost useless for irrigation purposes, and available as means of communication only for short distances in their lower reaches, where they flow through the narrow alluvial strips of level coast-lands to the sea. Even the Rio Grande del Norte, which is by far the largest, and which forms the frontier line between Mexico and Texas, is navigable by large vessels only for a few miles above its port of Matamoras. The Rio Grande de Santiago, the largest on the Pacific side, is almost everywhere obstructed by falls and rapids. On this coast the next in importance is the Mercala, or Rio de las Balsas, which, like the Panuco, Alvaredo, Coatzacoalas, Grijalva, and Usumacinta flowing to the Gulf of Mexico, is subject to sudden freshets during the rains.

At this season the waters which find no seaward outlet are collected in the depressions of the plateaus, where extensive tracts remain flooded for several months at a time. But these lacustrine basins of the Anahuac and Chihuahua table-lands, standing at elevations of from 4000 to 7000 feet, are, by evaporation under semi-tropical suns, rapidly reduced to their normal level. The diminished size of the Anahuac lakes shows that since the conquest a steady process of desiccation has been going on, due probably to the reckless destruction of the upland forests by the European settlers. None of these lakes are of great size except Lake Chapala, which is traversed by the Rio Grande de Santiago, and has a reputed area of about 1300 square miles. Amongst those of the plateau especially noteworthy for their magnificent scenery are Tezcuco and Chalco, in whose sparkling waters are reflected the surrounding volcanic peaks and extinct craters of the Anahuac table-land, with a background formed by the Cordilleras, whose snowy summits rise here and there high above the dark pine forests of the lower slopes.

Geology and minerals.

In the higher ranges the prevailing formations are granites, which seem also to form the foundation of the plateaus, above which rise the traps, basalts, mineral-bearing porphyries, and more recent lavas. Hence Lyell's theory that Mexico consisted originally of granitic ranges with intervening valleys subsequently filled up to the level of the plateaus by subterranean eruptions. Igneous rocks of every geologic epoch certainly to a large extent form the superstructure of the central plateau. But the Mexican table-land seems to consist mainly of metamorphic formations, which have been partly upheaved, partly interpenetrated and overlaid by igneous masses of all epochs, and which are chiefly represented by shales, greywacke, greenstones, silicious schists, and especially unfossiliferous limestone. All these formations are alike remarkable for the abundance and variety of their metalliferous ores, such as silver, silver-glance, copper, and gold. Gneiss and micaceous schists prevail in Oajaca and on all the southern slopes facing both oceans. But the highest ranges are formed mainly of plutonic and volcanic rocks, such as granites, syenites, diorites, mineral-bearing trachytes, basalts, porphyries, obsidian, pearlstone, sulphur, pumice, lavas, tufa, and other recent volcanic discharges. Obsidian (*itztli*) was the chief material formerly used by the natives in the manufacture of their cutting implements, as shown by the quarries of the Cerro de las Navajas ("Knife Cliff") near Zimapan. Vast deposits of pumice and the purest sulphur are found at Huichapa and in many of the craters. But immeasurably the most valuable rocks are the argentiferous porphyries and schists of the central plateau and in Sinaloa, unless they are destined to be rivalled by the auriferous deposits of Sonora.[2] Horizontal and stratified rocks, of extremely limited extent in the south, are largely developed in the northern states, and chalk becomes very prevalent towards the Rio Grande and Rio Gila valleys. To this chalk and to the sandstones are probably to be referred the sandy plains which cover vast tracts in North Mexico, stretching thence far into New Mexico and Texas. Here the Bolson de Mapimi, a vast rocky wilderness inhabited only by wild tribes, occupies a space of perhaps 50,000 square miles in Coahuila and parts of the surrounding states.

None of the horizontal layers seem to be very rich in ores, which are found mainly in the metamorphic, palæozoic, and hypogene rocks of Durango, Chihuahua, and the south. Apart from Sinaloa and Sonora, which are now known to contain vast stores of the precious metals, nearly all the historical mines lie on the south central plateau at elevations of from 5500 to 9500 feet. A line drawn from the capital to Guanajuato, and thence northwards to the mining town of Guadalupe y Calvo in Chihuahua, and southwards to Oajaca, thus cutting the main axis of upheaval at an angle of 45°, will intersect probably the richest known argentiferous region in the whole world. The central group of mines in the three mineral districts of Guanajuato, Zacatecas, and Catorze (San Luis Potosi), which have yielded more than half of all the silver hitherto found in Mexico, lie between 21° and 24° 30′ N., within an area of about 13,000 square miles. Here the Veta Madre lode of Guanajuato alone produced £504,000 between 1556 and 1803, besides £10,000 of gold. This metal, however, occurs chiefly, not on the plateau in association with silver, but on the slopes facing the Pacific, and apparently in greatest abundance in Sonora, near the auriferous region of New California. In recent times over half of the silver produced in the whole world has been supplied by Mexico, and the total yield of the precious metals between 1537 and 1880 was as under:[3]—

	Gold.	Silver.	Total.
1537 to 1821......	£14,000,000	£418,000,000	£432,000,000
1821 to 1880......	10,000,000	180,000,000	190,000,000
Total...........	£24,000,000	£598,000,000	£622,000,000

Of other minerals the most important are copper, found in a pure state near the city of Guanajuato, and associated with gold in Chihuahua, Sonora, Guerrero, Jalisco,

[1] "Near the mountain ranges, from which the water after heavy rains rushes down in innumerable forest streams, these ravines are filled with incredible rapidity as high as 30 feet,—the torrent importing (*sic*) trees and bearing away rocks with a thundering noise and irresistible power" (Egloffstein, p. 22).

[2] On the general character and distribution of the igneous formations Von Egloffstein remarks: "Intimate relations exist between the metalliferous and non-metalliferous porphyries. The metalliferous porphyry is less frequent, but constitutes the most important formation, bearing the precious metals, . . . embracing the rich lodes of Real-del-Monte, Pachuca, Chico, Capula, and Santa Rosa, all of great richness and magnitude. They further form the mineral districts of Angangueo, Oro, Huautla, &c., and part of the mountains of Zimapan and Istapa-del-Oro. The lodes found in this porphyry are characterized by their magnitude and the consistency of the ores they contain. . . . The richest ores of native silver and sulphuret, chloride, and oxide of silver are found in the lodes of Real-del-Monte, Pachuca, and Santa Rosa. . . . The gold seems to exist in small particles in the metamorphic porphyry mountains, whence it is carried by the rains to the valleys as the rocks become disintegrated" (pp. 6–8).

[3] *Times* correspondent, December 7, 1882. Guanajuato seems to be still the greatest producer, yielding from £1,500,000 to £1,750,000 yearly, although the great Valenciana mine is flooded, and of the hundred opened only fifty-two are now worked (Geiger).

Michoacan, and elsewhere; iron in immense masses in Michoacan and Jalisco, and in Durango, where the Cerro del Mercado is a solid mountain of magnetic iron ore; lead associated with silver, especially in Oajaca; tin in Michoacan and Jalisco; sulphur in many craters; platinum recently found in Tlaxcala and Hidalgo; cinnabar also recently in Morelos and Guerrero; "steppe salt" in the sandy districts of the north; "bitter salt" at Tepeyac; coal in limited quantities at various points; bismuth in many parts; marble, alabaster, gypsum, and rock-salt in great abundance throughout the plateau and the sierras. In 1882 there were open altogether 569 mines:—541 silver, 14 gold, 4 copper, 4 lead, 3 salt, 2 coal, and 1 mercury.[1]

Climate and vegetation. Intersected about midway by the Tropic of Cancer, and stretching across seventeen parallels of latitude, Mexico, from its position alone, necessarily enjoys a great diversity of climate. But from its peculiar configuration this feature is affected far more by the relief of the land than by its distance from pole or equator. This is especially true of the more fertile and populous section lying within the torrid zone, where three distinct climatic regions are distinguished, not according to their horizontal, but according to their vertical position. The temperature falling steadily with the elevation of the land, which here rises rapidly from sea-level to nearly 18,000 feet above the surrounding waters, the low-lying coast-lands, up to about 3000 feet on the scarps and terraces of the central plateau, are comprised within the first zone of *tierras calientes*, or "hot lands." Within this zone are included all the sandy and marshy tracts fringing the Gulf of Mexico, the lower slopes facing eastwards and exposed to the hot and moist winds from the Caribbean Sea, and most of Yucatan and the Tehuantepec isthmus, besides the narrow strip between the uplands and the Pacific which broadens northwards along the east side of the Gulf of California. Here the mean temperature varies from 77° to 82° Fahr., seldom falling below 60°, but often rising to 105°, and in the sultry districts of Vera Cruz and Acapulco to 110°. The extreme north-western parts of this region come almost within the rainless zone, and the Californian peninsula itself is subject to excessive droughts, rendering it almost uninhabitable. But farther south the climate on both seaboards may be described as humid, hot, and extremely unhealthy, especially for Europeans. Yellow fever and black vomit are here endemic. But these scourges are at least compensated by a magnificent tropical vegetation and extensive virgin forests abounding in valuable timbers, dyewoods, and medicinal and other useful plants. Of the 114 species of trees and cabinet woods, 17 of oil-bearing plants, and over 60 of medicinal plants and dyewoods indigenous to Mexico, and often differing specifically from kindred varieties in Central and South America, by far the larger part are represented in the tierras calientes. Amongst the most important of these forest plants are mahogany, rosewood, copal, caucho (india-rubber), jalap, sarsaparilla, and vanilla. Here also maize, supplying the staple food of the people, yields prodigious returns, multiplying from two hundred to four hundred fold, and affording two, three, and even four successive crops within the year. Rice, indigo, cotton, tobacco, and coffee all thrive well, while sugar, cocoa, the banana, and several varieties of beans are largely cultivated. The tobacco of Vera Cruz and Tabasco, the coffee of Colima, and the cocoa of Oajaca and Chiapas are of unrivalled excellence.

To the "hot lands" succeed in vertical position the *tierras templadas*, or "temperate lands," which comprise all the higher terraces and the central plateaus themselves between about 3000 and 8000 feet. With a mean temperature of from 62° to 70° Fahr., and oscillating between such moderate extremes as 50° and 86°, this region enjoys one of the very finest climates on the globe. The Puebla and Anahuac table-lands are described by enthusiastic travellers as "terrestrial Edens," with a perennial spring symbolized by the evergreen oak, cedars, and many analogous plants, which here attain their greatest perfection. The transition from the lower zone is often very gradual; and, while endemic fevers cease altogether at altitudes of 2700 and 2800 feet, the tropical flora invades many parts of the terrace lands, and even of the plateaus to heights of 4000 and 5000 feet.[2] A certain uniformity is thus imparted to the Mexican landscape by the wide range of the maize, wheat, tobacco, vine, coffee, and other plantations, as well as by the palms, evergreens, mango, olive, orange, lemon, yucca, and an endless variety of the cactus family, one species of which forms hedges 20 feet high on the Anahuac uplands. The central zone is on the whole drier than the southern lowlands, although the scarps facing seawards are often wrapped in the fogs and mists of the intercepted moisture-charged atmospheric currents. The heaviest recorded rainfall (90 to 100 inches) occurs in the healthy Huatusco district of Vera Cruz, at an altitude of 4380 feet.

In the highest zone of *tierras frias*, or "cold lands," embracing all the highlands from about 8000 feet upwards, the rainfall is five times less than on the tierras templadas. Hence snow rests throughout the year only on the four most elevated peaks of Popocatepetl, Orizaba, Nevada de Toluca (15,000 feet), and Ixtaccihuatl. Characteristic both of the tierras frias and templadas is the maguey (*Agave mexicana*), whose fruit is edible, and whose fermented juice has from time immemorial supplied the famous *pulque*, or national beverage of the Mexicans. From the fibre of the heniquen, an allied species, is produced the "Sisal hemp" of commerce, which has in recent years become the staple export of Yucatan.

Speaking generally, the four seasons are clearly marked north of 28° N. lat. only. South of that parallel they merge in the *estacion de las aguas*, or rainy season, from May to October, and the *estacion seca*, or dry season, which prevails for the rest of the year. The rains generally begin on the east coast, gradually moving westwards. In the Pacific the moist atmospheric currents are deflected northwards, whence the striking contrast between the

[1] Lorenzo Castro, *Mexico in* 1882. According to this authority the total yield of the Mexican mines between 1537 and 1880 was £776,276,000, while another estimate based on a report of the Mexican mint gives it at £930,786,000. Of this a large amount has been coined in Mexico, where there were eleven mints at work in 1876, with a total annual yield of about £5,000,000. The total coinage since the conquest has been estimated as high as £600,000,000, not more than 5 per cent. of this being gold. With regard to coal, the existence of which in Mexico has been recently denied by Mr Bigelow in *Harper's Magazine*, official returns for 1882 give a list of over twenty places where it has been found, though nowhere as yet in large quantities. Petroleum also appears to be very abundant in several localities. Amongst other natural products mention should be made of amber, found on the Yucatan coast. Mineral springs are very numerous everywhere on the plateaus and terrace-lands. The most famous are El Peñon and N. Señora de Guadelupe near the capital, and Aguas Calientes farther north.

[2] On the Amilpas plateau, which stretches south of Popocatepetl at a mean height of 5000 to 5400 feet, "coffee, sugar, and indigo are cultivated, and most of the tropical fruits grow luxuriantly" (Egloffstein, p. 17). The same authority gives the limits of vegetation in this region at 12,614 feet, and the snow-line at 14,960 feet. He observes that "nothing is more surprising to the traveller than the varieties of climate under this zone, which vary according to the different elevations above the sea. In a few hours we descended from the cold regions of the fir and the oak, on the heights of Ozumba, to a hot climate, *tierra caliente*, where we found the most luxuriant vegetation, passing in that short time through successive changes of the most diversified species of trees, plants, birds, insects" (p. 22).

the regular clergy suppressed, and their monasteries, together with all other superfluous ecclesiastical structures, appropriated by the state. During the last few years American Protestant missions have claimed some partial success, and the so-called "Church of Jesus," an undenominational body of a somewhat original type, has found a number of adherents, especially on the Anahuac tableland. But the *Indios bravos*, or uncivilized aborigines, everywhere follow the old spirit worship, while the Christianity of the Fideles is little more than a cloak for the continuous practice of the former Aztec heathenism. The pomp of the Roman ritual is supplemented by the feasts of the national worship, and the Pagan deities of the old cult are still represented by the saints of the Roman calendar.[1]

Administration.

Mexico constitutes at present a confederation of states modelled on that of the North-American Union, and administered according to the constitution of 1857 as amended in 1873–74. By popular suffrage are chosen the president, the upper house (fifty-two members), and the supreme judiciary for four years, and the lower house (two hundred and twenty-seven members) for two years. The senate, abolished in 1853, was restored in 1874, and the chief justice is *ex officio* vice-president. The federal states, which are divided into a number of administrative districts, enjoy full autonomy in all local matters. The several constitutions are modelled on that of the central government, and like it comprise three departments—legislative, executive, and judicial. Each state is represented in the federal congress in the proportion of one member for every 80,000 inhabitants, and in the federal senate by two members elected by suffrage in the local congress. All external affairs and questions of general interest are reserved for the central government. The constitution as now established thus represents in theory the complete overthrow of mediævalism, and the absolute triumph of the new ideas which in the Old World are still in so many places struggling for the ascendency.

History. Colonial period.

It is this struggle between privilege and popular rights that lends its human interest to the otherwise monotonous record of unresisted oppression and apparently aimless revolutions which characterize the early and the later periods of Mexican history, from the overthrow of the native rule down to the present day. The early or colonial period covers exactly three hundred years,—from the death in 1521 of Guatemozin, last of the Aztec emperors, to the withdrawal of the last Spanish viceroy, Don Juan O'Donoju, in 1821. During these three centuries the attitude of the masses was one rather of sullen submission than of active resistance to grinding oppression. By the Spanish Government Mexico was looked on merely as a vast metalliferous region, to be jealously guarded against foreign intrusion and worked exclusively for the benefit of the crown. The natives were evangelized chiefly for the purpose of being employed as slaves above and below ground, and thus was introduced from the West Indies the system of *repartimientos*, or distribution of the aborigines on the plantations and in the mines. But, while this system proved fatal to the natives of Cuba and Hayti, where it had to be replaced by negro labour, the hardier populations of the Anahuac plateau successfully resisted its blighting influences. It proved in fact more disastrous to the oppressor than to the oppressed. In those days Spain was commonly compared to a sieve, never the richer for all the boundless wealth drawn from the New World. But the aborigines derived at least some advantage from contact and partial fusion with a people of superior culture. This fusion, which may be regarded as the chief outcome of the colonial administration, has contributed to the formation of the present exceedingly complex Mexican nationality, in which the Indian continues to be the predominating element. Taking the whole population at less than ten millions, its ethnical distribution appears to be at present as under:—

1. Full-blood Indians	5,000,000
2. Mestizoes (half-caste Indians and whites)	3,000,000
3. Creoles (whites of Spanish descent)	1,500,000
4. Gachupines[2] (Spaniards by birth)	50,000
5. Other Europeans and Americans	100,000
6. Full-blood negroes	10,000
7. Zambos or "Chinos" (Indo-Africans)	45,000
8. Mulattoes (Eurafricans)	5,000

Under the Spanish administration, which was marked on the surface by few stirring events, such as warlike expeditions, civil strife, or serious internal troubles, Mexico, or New Spain, formed a viceroyalty at one time stretching from the isthmus of Panama to Vancouver's Island. Antonio de Mendoza, appointed in 1535 after government by *audiencias* had proved a signal failure, was the first of sixty-four viceroys who ruled with almost autocratic power, but scarcely any of whom has left a name in history. Don Juan de Acuña (1722–34) is mentioned as having been the only native American among them, and Don Juan V. G. Pacheco (1789–94) had at least the merit of betraying some regard for the social welfare of his subjects. Under him a regular police, the lighting and draining of towns, and other municipal improvements were introduced.

But down to the early years of the present century all emoluments in church and state, most of the large plantations, of the mines, and of the commerce of the country, continued to be monopolized by the privileged gachupines, whom the creoles and mestizoes had already begun to regard as aliens. Hence the first reactionary movements, stimulated by Napoleon's deposition of King Ferdinand and arrest of the viceroy Hurrigaray in 1808, were aimed rather against odious class distinctions and the intolerable oppression of these aliens than against the abstract rights of the Spanish crown. The long smouldering spirit of discontent at last broke into open revolt in 1810 at Guanajuato, under the leadership of Don Miguel Hidalgo. After his defeat and execution in 1811, the struggle was continued by Morelos, who, like Hidalgo, was a priest, and shared his fate in 1815. But he had already called a national assembly at Chilpanzinco, and by this body Mexican independence was for the first time proclaimed in 1813. A guerilla warfare kept the national spirit alive till a fresh stimulus was given to it by the Spanish revolution of 1820. Under the leadership of the "Liberator" Iturbide, Mexican independence was again proclaimed on February 24, 1821, and the same year the capital was surrendered by O'Donoju, the last of the viceroys. But even after the revolt had thus been crowned with success a change of *personnel* rather than of system was contemplated; nor was Iturbide proclaimed emperor until the Mexican crown had been declined by a royal prince of Spain.

Period of independence.

Almost simultaneously with this event the republican standard had been raised by Santa Anna at Vera Cruz (December 1822). Thus the nation had no sooner got rid of foreign rule than it became torn by internal dissension. But henceforth the struggle is not so much against the privileged classes as between Conservative and Liberal principles,—the former represented chiefly by the church and the superstitious populace, the latter by the more enlightened but not less unscrupulous sections of the community. From both the Indios Bravos, that is, about a third of the whole population, hold entirely aloof, and take advantage of the public disorders to continue their aggres-

[1] On the general state of religion in Mexico Bates well remarks:—"The educated classes conform to the outward ceremonies and ordinances of the church, while inwardly believing little or nothing of its dogmas. The lower grades of society are, on the other hand, steeped in the most grovelling superstition, intensified by many traditional Indian reminiscences. This section of the community yields a blind obedience to the clergy, notwithstanding the severe laws with which the Government has endeavoured to counteract the influence of the priests. Even so recently as 1874 a genuine case of witch-burning occurred in Mexico."—*Central America*, p. 34.

[2] From the Aztec *Catzopin*, centaur; also known as *Chapetones*.

sive warfare against all alike.[1] Events now follow in quick succession, and as many as three hundred successful or abortive revolutions are recorded during the brief but stormy life of Mexican national independence.[2] But amid the confusion of empires, republics, dictatorships, and military usurpations, succeeding each other with bewildering rapidity, the thoughtful student will still detect a steady progress towards the ultimate triumph of those Liberal ideas which lie at the base of true national freedom. A brief tabulated summary of the more salient incidents in this eventful struggle must here suffice:—

1821–23. Mexican independence acknowledged by Spain; regency under Iturbide, who (1822) is elected hereditary constitutional emperor; in December Santa Anna proclaims the republic in Vera Cruz.

1823–24. Provisional Government; Iturbide abdicates; exiled, withdraws to London, but returning is shot (1824).

1824. First Liberal constitution,—"Acta Constitutiva de la Federacion Mexicana," then comprising nineteen states and five territories; first president D. Felix Victoria, known as "Guadalupe Victoria."

1828–30. Contested presidencies of Pedraza, Guerrero, and Bustamente.

1835. Reaction of the church party; constitution of 1824 abolished; the confederate states fused in a consolidated republic under Santa Anna as president, but practically dictator.

1836. Texas refusing to submit secedes, defeats and captures Santa Anna.

1837. Santa Anna returning resumes office.

1839. Bravo's brief presidency followed by much anarchy.

1841–44. Santa Anna's first dictatorship with two others.

1844. Constitution restored with Santa Anna president; banished same year, he is succeeded by Canalizo.

1845. Herrera president; disastrous war with United States to recover Texas.

1846. Santa Anna again president.

1848. Treaty of Guadalupe; California and New Mexico ceded to United States.

1853. Santa Anna's second dictatorship; treaty of Mesilla (negotiated by Gadsden) ceding extensive territory to United States and reducing Mexico to its present limits; great financial embarrassment; "Plan of Ayutla"; flight of Santa Anna followed by universal chaos.

1855. Provisional Government under President Comonfort.

1856. Constitutional convention; radical reforms; rupture with Spain.

1857. Liberal constitution of March 11; suspended December 1; Comonfort dictator; the reaction supported by the church, large part of the army, and all Conservatives; opposed at Vera Cruz by Vice-president Benito Juarez at the head of the "Puros," or advanced Liberals; the "War of Reform" begins, and lasts till 1860.

1858–59. In the capital Comonfort is deposed by Zuloaga, who abdicates in favour of Miramon, general of the Conservative forces; but, declining the presidency, Miramon restores Zuloaga; British legation violated; in Vera Cruz the United States envoy MacLean acknowledges Juarez, who introduces further Liberal measures.

1860. Capitulation of Guadalajara; flight of Miramon from the capital; triumph of the Liberals.

1861. Triumphal entry of Juarez into the capital; further radical reforms; marriage declared a civil contract; celibacy and ecclesiastical tribunals suppressed; confiscation of church property valued at £75,000,000 and over a third of the soil; final separation of church and state; Spain, France, and England urge claims for losses of their subjects resident in Mexico; convention of London; intervention of the allies, who occupy Vera Cruz in December.

1862. England and Spain withdraw, their claims having been settled by negotiation; war continued by France.

1863–64. The capital occupied by the French; Louis Napoleon dreams of a universal fusion of the Latin races; offers the Mexican imperial crown to the Austrian archduke Ferdinand Maximilian, who accepts, and arrives in June 1864.

1867. After diverse issues the French withdraw; Maximilian, abandoned to his fate, is captured and shot at Querétaro (June 19).

1867–69. Various pronunciamientos by Santa Anna and others.

1871–72. Juarez president; he dies in office July 1872; succeeded by his secretary Lerdo de Tejada.

1873–74. The Liberal constitution of 1857, which had been twice suspended (1858–60 and 1863–67), is now largely amended, and continues to be henceforth the organic law of Mexico.

1876. Tejada succeeded by Porfirio Diaz.

1880. Manuel Gonzalez, reigning president

Since 1869 the Liberal party has succeeded in preserving peace at home and abroad, while establishing democratic institutions on a firm basis. A. v. Humboldt's gloomy anticipations[3] have not been realized, and for the first time in its chequered history Mexico may look forward with some confidence to a bright future. The plague spot is the uncivilized Indian element. But with boundless natural resources at its disposal, a wise administration may hope to overcome that difficulty, and gradually effect a complete fusion of the antagonistic racial elements.

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III. THE CITY OF MEXICO.

Mexico, the capital formerly of the Aztec empire and of the Spanish colony of New Spain, and now of the republic, state, and federal district of Mexico, stands on the Anahuac plateau, 7524 feet above sea-level, 2½ miles from the south-west side of Lake Tezcuco (Texcoco), the lowest and largest of six basins filling the deepest depression in the hill-encircled Mexican valley. Situated in 19° 25′ 45″ N. lat. and 99° 7′ W. long., it is 173 miles by rail from Vera Cruz on the Atlantic, 290 from Acapulco on the Pacific, 285 from Oajaca, 863 from Matamoros on the United States frontier. Mexico is the largest and finest city in Spanish America, forming a square nearly 3 miles both ways, and laid out with perfect regularity, all its six hundred streets and lanes running at right angles north to south and east to west, and covering within the walls an area of about 10 square miles, with a population (in 1880) of 230,000. Most of the inhabitants are pure-blood Indians or mestizoes; but the foreigners, chiefly French, English, Germans, Americans, and Spaniards, monopolize nearly all the trade, and as capitalists, bankers, merchants, and dealers enjoy an influence out of all proportion to their numbers. A large portion of the natives are mendicants or vagrants, and the distinctly criminal element (26,470 in 1878) is kept in order by a police force of 1320 men; yet in that year there were as many as 5370 knife-attacks and 3250 robberies. The

[1] In December 1882 a party of seventy-five Mexicans and Americans were massacred in the state of Chihuahua by a band of Bravos.

[2] Between 1821 and 1868 the form of government was changed ten times; over fifty persons succeeded each other as presidents, dictators, or emperors; both emperors were shot, Iturbide in 1824, Maximilian in 1867, and according to some calculations there occurred at least three hundred *pronunciamientos*.

[3] Consulted shortly before his death as to the future prospects of Mexico, with which his name was so intimately associated, Humboldt ventured to prophesy that "die Vereinigten Staaten werden es an sich reissen und dann selbst zerfallen."

broad, well-paved, and gas-lit streets present a picturesque appearance with their quaint two- and three-storied stone houses gaily painted in white, red, yellow, or green, and terminating everywhere with a background of rugged sierras or snowy peaks which, owing to the bright atmosphere at this elevation, seem quite close, although really 30 or 40 miles distant. All the main thoroughfares converge on the central Plaza de Armas (Plaza Mayor, or Main Square), which covers 14 acres, and is tastefully laid out with shady trees, garden plots, marble fountains, and seats. Here also are grouped most of the public buildings, towering above which is the cathedral, the largest and most sumptuous church in America, which faces the north side of the plaza on the site of the great pyramidal teocalli or temple of Huitzilopochtli, titular god of the Aztecs. This edifice, which was founded in 1573 and finished in 1657, at a cost of £400,000 for the walls alone, forms a Greek cross 426 feet long and 203 wide, with two great naves and three aisles, twenty side chapels, and a magnificent high altar supported by marble columns, and surrounded by a tumbago balustrade with sixty-two statues of the same rich gold, silver, and copper alloy serving as candelabra. The elaborately carved choir is also enclosed by tumbago railings made in Macao, weighing 26 tons, and valued at about £300,000. In the interior the Doric style prevails, Renaissance in the exterior, which is adorned by a fine dome and two open towers 218 feet high. At the foot of the left tower is placed the famous calendar stone, the most interesting relic of Aztec culture. The east side of the plaza is occupied by the old viceregal residence, now the National Palace, with 675 feet frontage, containing most of the Government offices (ministerial, cabinet, treasury), military headquarters, archives, meteorological department with observatory, and the spacious hall of ambassadors with some remarkable paintings by Miranda and native artists. North of the National Palace, and apparently forming portions of it, are the post-office and the national museum of natural history and antiquities, with a priceless collection of Mexican remains. Close to the cathedral stands the Monte de Piedad, or national pawnshop, a useful institution, endowed in 1744 by Terreros with £75,000, and now possessing nearly £2,000,000 of accumulated funds. Facing the cathedral is the Palacio Municipal (city hall), 252 feet by 122, rebuilt in 1792 at a cost of £30,000, and containing the city and district offices, the corporation jail, and the lonja, or merchants' exchange. Around the Plaza San Domingo are grouped the convent of that name, said to contain vast treasures buried within its walls, the old inquisition, now the school of medicine, and the custom-house. In the same neighbourhood are the church of the Jesuits and the school of arts, "an immense workshop, including iron and brass foundries, carriage and cart mending, building and masonry, various branches of joinery and upholstery work, and silk and cotton hand-weaving" (Brocklehurst). Other noteworthy buildings are the national picture gallery of San Carlos, the finest in America, in which the Florentine and Flemish schools are well represented, and which contains the famous Las Casas by Felix Parra; the national library of St Augustine, with over 100,000 volumes, numerous MSS., and many rare old Spanish books; the mint, which since 1690 has issued coinage, chiefly silver, to the amount of nearly £400,000,000; the Iturbide hotel, formerly the residence of the emperor Iturbide; the Mineria, or school of mines, with lecture-rooms, laboratories, rich mineralogical and geological specimens, and a fossil horse 3 feet high of the Pleistocene period. Owing to the spongy nature of the soil, the Mineria and many other structures have settled out of the perpendicular, thus often presenting irregular lines and a rickety appearance. Among the twenty scientific institutes mention should be made of the Geographical and Statistical Society, whose meteorological department issues charts and maps of unsurpassed excellence.

Besides the chief market south of the National Palace there are three others, all well stocked with meat, fish, and especially vegetables, fruits, and flowers grown mainly on the *chinampas*, or floating gardens of Lakes Chalco and Xochimilco. These gardens, which were far more numerous in the Aztec times, are formed by placing layers of turf on the matted aquatic vegetable growths to a height of 2 or 3 feet above the water, and securing them by long willow poles driven through them to the bottom, where they take root. They form plots 100 to 200 feet long by 20 to 100 broad, and are firm enough to support the huts of the cultivators. From the still extant illuminated tribute-rolls it appears that the Aztec rulers derived a large share of the taxes from these gardens, which at that time also covered the brackish waters of Lake Tezcuco.

Before 1860 half of the city consisted of churches, convents, and other ecclesiastical structures, most of which have been sequestrated and converted into libraries, stores, warehouses, and even stables, or pulled down for civic improvements. Nevertheless there still remain fourteen parish and thirty other churches, some of large size with towers and domes, and their number has now been increased by six Protestant churches including the Anglican cathedral in San Francisco Street. This is the leading thoroughfare, and is rivalled in splendour only by the new Cinco de Mayo Street running from the National Theatre to the cathedral.

The city is supplied by two monumental aqueducts, from Chapultepec and the south-west, with good water at the rate of 44 gallons per day per inhabitant.

Its industries are varied but unimportant, consisting chiefly of gold and silver work, coarse glazed and unglazed pottery of peculiar form and ornamentation, paper, feather-work remarkable for its taste and beautiful designs, toys, rosaries, crucifixes, religious pictures, lace, and some weaving.

Mexico enjoys an equable climate, with a temperature varying from 70° to 50° F., but rendered unhealthy by the exhalations from the lakes and the bad drainage. The death-rate in 1876 was 59 per 1000, and 45 in 1878, pneumonia being most fatal (12 per cent. of the total). Standing at the lowest level of a lacustrine valley, 1400 square miles in extent, and completely encircled by hills with no natural outlet, the city has always been subject to floodings from the overflow of the neighbouring freshwater Lakes Zumpango and Xaltocan on the north and Xochimilco and Chalco on the south, which, in the 17th century, laid the whole district under water in 1607, and again for five years from 1629 to 1634. To remedy the evil the engineer Martinez began in 1607 the great cutting 13 miles long through the Nochistongo hill in order to draw off the discharge of Lake Zumpango, the highest in the valley, to the river Tula, a tributary of the Panuco, flowing to the Atlantic. This work, which cost the lives of 70,000 natives, was completed in 1789; but the result was not satisfactory, and the city is still often flooded.

The chief public promenades are the Alameda, planted with stately beeches; the Vega, skirted by the Vega Canal, and adorned with the colossal bust of Guatemozin, the last of the Aztec emperors; the Paseo de la Riforma, a fine avenue 3 miles long running south to the famous castle of Chapultepec, a place intimately associated with the names both of Montezuma and Maximilian. The present castle, erected in 1785 by the viceroy Galvez on the site of Montezuma's palace, commands a superb view of the city and surrounding district, and is approached by avenues of gigantic cypresses (*Cupressus disticha*) dating from Aztec times, growing to a height of 120 feet, and measuring from 30 to 40 feet round the stem. Other good roads with horse or steam trams lead to Tacubaya and the "Noche Triste" tree, where Cortes is traditionally supposed to have rested after the disastrous retreat from Mexico on the night of June 30, 1520, to the pleasant summer suburb of Tacubaya, and to the renowned shrine of Our Lady of Guadalupe, 3 miles to the east on the border of Lake Tezcuco. Here stands the most famous church in Mexico, erected to commemorate the legendary apparitions of the Madonna to the Indian Juan Diego in December 1531, and still visited by thousands of pilgrims or sightseers.

Mexico dates either from the year 1325 or 1327, when the Aztecs after long wanderings over the plateau were directed by the oracle to settle at this spot. For here had been witnessed the auspicious omen of an eagle perched on a nopal (cactus) and devouring a snake. Hence the original name of the city, Tenochtitlan (nopal on a stone), changed afterwards to Mexico in honour of the war god Mexitli. With the progress of Aztec culture the place rapidly improved, and about 1450 the old mud and rush houses were replaced by solid stone structures erected partly on piles amid the islets of Lake Tezcuco, and grouped round the central enclosure of the great teocalli. The city had reached its highest splendour on the arrival of the Spaniards in 1519, when it comprised from 50,000 to 60,000 houses, with perhaps 500,000 inhabitants, and seemed to Cortes "like a thing of fairy creation rather than the work of mortal hands" (Prescott). It was at that time about 12 miles in circum-

ference, every where intersected by canals, and connected with the mainland by six long and solidly constructed causeways, as is clearly shown by the plan given in the edition of Cortes's letters published at Nuremberg in 1524 (reproduced in vol. iv. of H. H. Bancroft's *History of the Pacific States*, San Francisco, 1833, p. 280). After its almost total destruction in November 1521, Cortes employed some 400,000 natives in rebuilding it on the same site; but since then the lake seems to have considerably subsided, for although still 50 square miles in extent it is very shallow, and has retired 2½ miles from the city. During the Spanish rule the chief event was the revolt of 1692, when the municipal buildings were destroyed. Since then Mexico has been the scene of many revolutions, and after the battle of Chapultepec (September 13, 1847) the city was held by the United States troops till the treaty of Guadalupe, May 1848. But since the disorders ending with the death of Maximilian it has turned to peaceful ways, and has become a great centre of civilizing influences for the surrounding semi-barbarous peoples. (A. H. K.)

MEYERBEER, Giacomo (1791–1863), first known in Germany as Jakob Meyer Beer, was born at Berlin on September 5, 1791,[1] of a wealthy and talented Jewish family. His father, Herz Beer, was a banker; his mother, Amalie (*née* Wulf), was a woman of high intellectual culture; and two of his brothers distinguished themselves in astronomy and literature. He studied the pianoforte, first under Lauska, and afterwards under Lauska's master, Clementi. When seven years old he played Mozart's Concerto in D Minor in public, and at nine he was pronounced the best pianist in Berlin. For composition he was placed under Zelter, whose lessons were soon exchanged for those of Bernard Weber, then director of the Berlin opera, by whom he was introduced to the Abbé Vogler. Struck by his brilliant talent, Vogler invited him to Darmstadt, and in 1810 received him into his house, where he formed an intimate friendship with Karl Maria von Weber, who, though his senior by eight years, shared the daily lessons he received from the abbé in counterpoint, fugue, and extempore organ-playing. At the end of two years the grand-duke appointed Meyerbeer composer to the court. His early works, however, were far from successful,—his first opera, *Jephtha's Gelübde*, failing lamentably at Darmstadt in 1811, and his second, *Wirth und Gast* (*Alimelek*), at Vienna in 1814. These checks discouraged him so cruelly that he feared he had mistaken his vocation. Nevertheless, by advice of Salieri, he determined to study vocalization in Italy, and then to form a new style. But at Venice he was so captivated by the style of Rossini that, renouncing all thought of originality, he produced a succession of seven Italian operas—*Romilda e Costanza*, *Semiramide riconosciuta*, *Edouardo e Cristina*, *Emma di Rosburgo*, *Margherita d'Anjou*, *L'Esule di Granata*, and *Il Crociato in Egitto*—which all achieved a success as brilliant as it was unexpected. Against this act of treason to German art Weber protested most earnestly; and before long Meyerbeer himself grew tired of his defection, though the success of *Il Crociato* was so great that he was crowned upon the stage. An invitation to Paris in 1826 led him to review his position fairly and dispassionately, and he could not conceal from himself the fact that he was wasting in imitation powers which, rightly used, might make his name immortal. For several years after this he produced nothing in public; but, in concert with Scribe, he planned the work which first made known the reality of his transcendent genius—his first French opera, *Robert le Diable*. This gorgeous drama was produced at the Grand Opéra in 1831, and received with acclamation. It was the first of its race; a grand romantic opera, abounding with scenes of startling interest, with situations more powerfully dramatic than any that had been attempted either by Cherubini or Rossini, with mysterious horrors and chivalric pomp, and with ballet music such as had never yet been heard, even in Paris. Its popularity exceeded all previous expectation; yet for five years after this signal triumph Meyerbeer appeared before the public no more. We cannot doubt that his motive for this retirement was the determination to produce something greater still; and in some respects his next opera, *Les Huguenots*, really was greater, though it fell short of the deep romance which rendered *Robert le Diable* so incomparably captivating.

The first performance of *Les Huguenots* took place in 1836. In gorgeous colouring, in depth of passion, in consistency of dramatic treatment, and in careful delineation of individual character, it is at least the equal of *Robert le Diable*. In two points only did its interest fall short of that inspired by the earlier work. Meyerbeer had shown himself so great a master in his treatment of the supernatural that one regretted the unavoidable omission of that powerful element in his second grand opera; and, more important still, the fifth act of *Les Huguenots* was so arranged by the librettist as to render effective musical treatment impossible. The substitution of a noisy fusillade for a legitimate dramatic situation was fatal to the anticipated climax. The music which accompanies this division of the work is necessarily inferior to all that precedes it. The true interest of the drama culminates at the close of the fourth act, when Raoul, leaping from the window, leaves Valentine fainting upon the ground. The spectator needs not to be told that the former will be shot down the moment he arrives in the street, or that the latter will mourn for him to the end of her days. Neither musically nor dramatically does anything more remain to be said; and therefore it is that those who quit the theatre when the curtain falls for the fourth time carry away with them a far more perfect ideal than those who remain to the end.

After the production of *Les Huguenots* Meyerbeer again retired from public view, and spent many years in the preparation of two of his greatest works—the greatest of all except the two we have already mentioned—*L'Africaine* and *Le Prophète*. The libretti of both these operas were furnished by Scribe; and both were subjected to countless changes of detail before they satisfied the composer's fastidious taste; in fact, the story of *L'Africaine* was more than once entirely rewritten.

Meanwhile Meyerbeer accepted the appointment of kapellmeister to the king of Prussia, and spent some years at Berlin, where he produced *Ein Feldlager in Schlesien*, a German opera, in which the matchless cantatrice Jenny Lind made her first appearance in Prussia, with unprecedented success. Here also he composed, in 1846, the overture to his brother Michael's drama, *Struensee*. But his chief care at this period was bestowed upon the worthy presentation of the works of others. He began by producing his dead friend Weber's *Euryanthe*, with scrupulous attention to the composer's original idea. With equal unselfishness he procured the acceptance of *Rienzi* and *Der Fliegende Holländer*, the first two operas of Richard Wagner, who, then languishing in poverty and exile, would, but for him, have found it impossible to obtain a hearing in Berlin. With Jenny Lind as prima donna and Meyerbeer as conductor, the opera flourished brilliantly in the Prussian capital; but the anxieties of this thankless period materially shortened the composer's life.

Meyerbeer produced *Le Prophète* at Paris in 1849; and, if it did not at first create so great a sensation as *Les Huguenots*, this was simply because it needed to be better

[1] Or, according to some accounts, 1794.

both men and women, are shorter and darker-complexioned than the Chinese, their faces also are rounder and their features sharper. In disposition, too, they are very unlike their civilized neighbours. They are brave, passionate, suspicious, revengeful, and indifferent to cold and hunger; they are free and easy in their manners, and are as noisily joyous as the Chinese are grave and sedate.

They are divided into between forty and fifty clans, each of which is distinguished by a name which is generally derived either from some physical characteristic, or from some custom, or from the habitat of the clan, as, for example, "The Black Miau," "the narrow-headed Miau," so named from their manner of dressing their hair, "the six-valley Miau," &c. Among these clans there exist wide differences of culture, some being in no way removed from savages, while others who have been brought under the influence of Chinese civilization show themselves apt and ready learners. Very few of them, so far as is known, possess any written records. The Yaou-jin, or Goblin clan, are said to have books, which, though they are now unable to read, they still regard with reverent awe. "The barbarous characters" used in these books are, according to a Chinese writer, "like knotted worms, and are utterly unintelligible." The Ko-los also are said to be a lettered clan, but for the most part the Miautse content themselves with conveying information and preserving records by means of notched sticks. Their language as well as their ethnic characteristics prove them to be closely related to the Siamese, Anamese, Cambodians, and the inhabitants of Hainan; in fact they form part of the race which is spread over the whole of south-eastern Indo-China. Their social customs are as widely different as their appearance is from those of the Chinese. The widest latitude is given to the youth of both sexes in the choice of their husbands and wives. As among the hill tribes of Chittagong, the selection is commonly made on the mountain side, where on moonlight nights in the "leaping month" the young men and maidens meet to sing or to play at ball, or to dance round the "devil's staff" (*Anglice*, Maypole), and to choose their partners for life. Among some clans the "couvade" is an established custom. Their funeral rites vary according to the districts, those living within reach of the influence of the Chinese having adopted their customs, while those more remote still hang their dead in baskets from trees, or lay them in the ground and disinter them yearly to wash their bones. In dress they are fond of bright colours, and commonly wear loose but short jackets, sometimes with and sometimes without trousers. The men wear turbans wound round their hair, which is raised above the head in the shape of a spiral shell, and the women either don a kind of cap, or dress their hair in the shape of a ram's horn. For many years the relations of the Miautse with the Chinese Government have been generally of a peaceable nature, and in the *Peking Gazette* of April 1881 there was published a new system of government by which it is hoped that the incorporation of the mountaineers into the empire may become more real and complete.

See *Sketches of the Miau-tsze*, translated by E.C. Bridgman; J. Edkins, *The Miau-tsi Tribes, their History*; and "Quaint customs in Kwei-chow," *Cornhill Magazine*, January 1872.

MICAH (מִיכָה) is the short form of a name which in various modifications—*Mīcāiāhū*, *Mīcāiĕhū*, *Mīcāiāh*—is common in the Old Testament, expressing as it does a fundamental point of Hebrew faith: Who is like Jehovah? The name was borne among others by the Danite whose history is given in Judg. xvii. *sq.*, by the prophet who opposed Ahab's expedition to Ramoth-Gilead (1 Kings xxii.), and by the subject of the present article, the contemporary and fellow-worker of Isaiah, whose name is prefixed to the sixth in order of the books of the minor prophets.[1]

It is at once apparent that the book of Micah divides itself into at least two distinct discourses, chap. vi. 1 forming a new commencement; and from what we know in general of the compilation of the prophetic collection we cannot at once determine whether the second discourse, which has no title, is to be ascribed to the author of the immediately preceding prophecy, or is to be regarded as an independent and anonymous piece. To decide this question, if it can be decided, we must begin by a separate study of the earlier chapters to which the title in Micah i. 1 directly belongs. These again fall into two parts. Chaps. i.–iii. (with the exception of two verses, ii. 12, 13) are a prediction of judgment on the sins of Judah and Ephraim. In a majestic exordium Jehovah Himself is represented as coming forth in the thunderstorm (comp. Amos i. 2) from His heavenly palace, and descending on the mountains of Palestine, at once as witness against His people, and the executer of judgment on their sins. Samaria is sentenced to destruction for idolatry; and the blow extends to Judah also, which participates in the same guilt (chap. i.). But, while Samaria is summarily dismissed, the sin of Judah is analysed at length in chaps. ii. and iii., in which the prophet no longer deals with idolatry, but with the corruption of society, and particularly of its leaders—the grasping aristocracy whose whole energies are concentrated on devouring the poor and depriving them of their little holdings, the unjust judges and priests who for gain wrest the law in favour of the rich, the hireling and gluttonous prophets who make war against every one "that putteth not into their mouth," but are ever ready with assurances of Jehovah's favour to their patrons, the wealthy and noble sinners that fatten on the flesh of the poor. The prophet speaks with the strongest personal sympathy of the sufferings of the peasantry at the hands of their lords, and contemplates with stern satisfaction the approach of the destroyer who shall carry into exile "the luxurious sons" of this race of petty tyrants (i. 16), and leave them none to stretch the measuring line on a field in the congregation of Jehovah (ii. 5). The centre of corruption is the capital, the city of Zion, grown great on the blood and wrongs of the provincials, the seat of the cruel princes, the corrupt judges and diviners. For their sake, he concludes, Zion shall be plowed as a field, Jerusalem shall lie in ruins, and the temple hill return to jungle (iii. 12).

The situation thus sketched receives its elucidation from the data supplied by the title (i. 1) and confirmed and rendered more precise by a remarkable passage in Jeremiah. According to the title Micah flourished in the reigns of Jotham, Ahaz, and Hezekiah; according to Jeremiah (xxvi. 18 *sq.*) the prophecy of the destruction of Jerusalem just cited was spoken under Hezekiah, and bore fruit in the repentance of king and people, by which the judgment was averted. The allusion beyond doubt is to Hezekiah's work of religious reformation (2 Kings xviii. 4 *sq.*). It is hardly possible to separate this reformation from the influence of Isaiah, which did not become practical in the conduct of the state till the crisis of Sennacherib's invasion; and the conclusion that Hezekiah was not from the first a reforming king, which is forced on us by many passages of Isaiah, is confirmed by the prophecy of Micah, which, after Hezekiah's accession, still represents wickedness as seated in the high places of the kingdom. The internal disorders of the realm depicted by Micah are also prominent in Isaiah's prophecies; they were closely connected, not only with the foreign complications due to the approach of the Assyrians, but with the break-up of the old agrarian system within Israel, and with the rapid and uncompensated aggrandisement of the nobles during those prosperous years when the conquest of Edom by Amaziah and the occupation of the port of Elath by his son (2 Kings xiv. 7, 22) placed the lucrative trade between the Mediterranean and the Red Sea in the hands of the rulers of Judah. On the other hand the democratic tone which distinguishes Micah from Isaiah, and his announcement of the impending fall of the capital (the deliverance of which from the Assyrian appears to Isaiah as the necessary condition for the preservation of the seed of a new and better kingdom), are explained by the fact that, while Isaiah lived in the centre of affairs, Micah was a Morasthite or inhabitant of Moresheth Gath, a place near the Philistine frontier so unimportant as to be mentioned

[1] A confusion between the two prophets of the name has led to the insertion in the Massoretic text of 1 Kings xxii. 28 of a citation from Micah i. 2, rightly absent from the LXX.

only in Micah i. 14.[1] The provincial prophet sees the capital and the aristocracy entirely from the side of a man of the oppressed people, and foretells the utter ruin of both. But this ruin does not present itself to him as involving the captivity or ruin of the nation as a whole; the congregation of Jehovah remains in Judæa when the oppressors are cast out (ii. 5); Jehovah's words are still good to them that walk uprightly; the glory of Israel is driven to take refuge in Adullam, as in the days when David's band of broken men was the true hope of the nation, but there is no hint that it is banished from the land. Thus upon the prophecy of judgment we naturally expect to follow a prophecy of the redintegration of Jehovah's kingship in a better Israel, and this we find in ii. 12, 13 and in chaps. iv., v. Both passages, however, present difficulties. The former seems to break the pointed contrast between ii. 11 and iii. 1, and is therefore regarded by Ewald as an example of the false prophecies on which the wicked rulers trusted. The thought, however, is one proper to all true prophecy (comp. Hos. i. 11 [ii. 2], Isa. xi. 11 *sq.*, Zeph. iii. 14, Jer. xxxi. 8), and precisely in accordance with chaps. iv., v., even in the details of expression and imagery.[2] It is indeed possible that these verses are a separate oracle of Micah, which did not originally stand in its present connexion. The sequence of thought in chaps iv., v., on the other hand, is really difficult, and has given rise to much complicated discussion.[3] There is a growing feeling among scholars that iv. 11–13 stands in direct contradiction to iv. 9, 10, and indeed to iii. 12. The last two passages agree in speaking of the capture of Jerusalem, the first declares Zion inviolable, and its capture an impossible profanation. Such a thought can hardly be Micah's; even if we resort to the violent harmonistic process of imagining that two quite distinct sieges, separated by a renewal of the theocracy, are spoken of in consecutive verses. An interpolation, however, in the spirit of such passages as Ezek. xxxviii., xxxix., Joel iii. [iv.], Zech. xiv., is very conceivable in post-exilic times, and in connexion with the growing impulse to seek a literal harmony of all prophecy on lines very different from the pre-exilic view in Jer. xxvi., that predictions of evil may be averted by repentance. Another difficulty lies in the words "and thou shalt come even to Babylon" in iv. 10. Micah unquestionably looked for the destruction of Jerusalem as well as of Samaria in the near future and by the Assyrians (i. 9), and this was the judgment which Hezekiah's repentance averted. If these words, therefore, belong to the original context, they mark it as not from Micah's hand; but it is easy to see that they are really a later gloss. The prophetic thought is that the daughter (population) of Zion shall not be saved by her present rulers or defensive strength; she must come down from her bulwarks and dwell in the open field; there, and not within her proud ramparts, Jehovah will grant deliverance from her enemies. This thought is in precise harmony with chaps. i.–iii., and equally characteristic is what follows in chap. v. Micah's opposition to present tyranny expresses itself in recurrence to the old popular ideal of the first simple Davidic kingdom (iv. 8) to which he had already alluded in i. 15. These old days shall return once more. Again guerilla bands (בת־גדוד) gather to meet the foe as they did in the time of Philistine oppression. A new David, like him whose exploits in the district of Micah's home were still in the mouths of the common people, goes forth from Bethlehem to feed the flock in the strength of Jehovah. The kindred Hebrew nations are once more united to their brethren of Israel (comp. Amos ix. 12, Isa. xvi. 1 *sq.*). The remnant of Jacob springs up in fresh vigour, inspiring terror among the surrounding peoples, and there is no lack of chosen captains to lead them to victory against the Assyrian foe. In the rejuvenescence of the nation the old stays of that oppressive kingship which began with Solomon, the strongholds, the fortified cities, the chariots and horses so foreign to the life of ancient Israel, are no more known; they disappear together with the divinations, the soothsayers, the idols, the *maççebas* and *asheras* of the high places Jehovah is king on Mount Zion, and no inventions of man come between Him and His people.

The elements of this picture, drawn so largely from the most cherished memories of the Judæans, could not fail to produce a wide impression, especially when the invasion of Sennacherib, although it spared Jerusalem, fulfilled in the most striking way a great part of Micah's predictions of judgment. Of this we have evidence, not only in Jer. xxvi., but in the political and religious ideas of the book of Deuteronomy. The picture of the right king (Deut. xvii. 14 *sq.*) and the condemnation of the high-places alike follow the doctrine of Micah.

A difficulty still remains in the opening verses of chap. iv. Micah iv. 1–3 and Isa. ii. 2–4 are but slightly modified recensions of the same text, and as Isa. ii. is older than the prophecy of Micah, while on the other hand Micah iv. 4 seems the natural completion of the passage, it is common to suppose that both copy an older prophet. But the words have little connexion with the context in Isaiah, and may be the quotation of a copyist suggested by ver. 5. On the other hand it has been urged that the passage belongs to a later stage of prophetic thought than the 8th century B.C. There is, however, no real difficulty in the idea that foreign nations shall seek law and arbitrament at the throne of the king of Zion (comp. the old prophecy Isa. xvi.); and the mention of the temple as the seat of Jehovah's sovereignty may be illustrated by Isa. vi., where the heavenly palace (Micah i. 3) is at least pictured in the likeness of the temple on Zion. At the same time the Jerusalem of Micah iv. 8 is the Jerusalem of David not of Solomon, the ideas of iv. 1–4 do not reappear in chap. v., and the whole prophecy would perhaps be more consecutive and homogeneous if iv. 6 (where the dispersed and the suffering are, according to chap. ii., the victims of domestic not of foreign oppression) followed directly on iii. 12.

The sixth chapter of Micah presents a very different situation from chaps. i.–v. Jehovah appears to plead with his people for their sins, but the sinners are no longer a careless and oppressive aristocracy buoyed up by deceptive assurances of Jehovah's help, by prophecies of wine and strong drink; they are bowed down by a religion of terror, wearied with attempts to propitiate an angry God by countless offerings, and even by the sacrifice of the first-born. Meantime the substance of true religion—justice, charity, and a humble walk with God—is forgotten, fraud and deceit reign in all classes, the works of the house of Ahab are observed (worship of foreign gods). Jehovah's judgments are multiplied against the land, and the issue can be nothing else than its total desolation. All

[1] That Micah lived in the Shephela or Judæan lowland near the Philistine country is clear from the local colouring of i. 10 *sq.*, where a number of places in this quarter are mentioned together, and their names played upon in a way that could hardly have suggested itself to any but a man of the district. The paronomasia makes the verses difficult, and in i. 14 none of the ancient versions recognizes Moresheth Gath as a proper name. The word Morasthite (*Mōrashti*) was therefore obscure to them; but this only gives greater weight to the traditional pronunciation with ō in the first syllable, which is as old as the LXX., and goes against the view, taken by the Targum both on Micah and on Jeremiah, and followed by some moderns (including Roorda), that Micah came from Mareshah. When Eusebius places Μωρασθεί near Eleutheropolis it is not likely that he is thinking of Mareshah (Maresa), for he speaks of the former as a village and of the latter as a ruin 2 miles from Eleutheropolis. Jerome too in the *Epit. Paulæ* (*Ep.* cviii.), speaking as an eye-witness, distinguishes Morasthim, with the church of Micah's sepulchre, from Maresa. This indeed was after the pretended miraculous discovery of the relics of Micah in 385 A.D.; but the name of the village which then existed (*Præf. in Mich.*) can hardly have been part of a pious fraud.

[2] The figure of the shepherd gathering a scattered flock certainly does not presuppose a total captivity, as Stade (*Z. f. A.T. W.*, i. 161 *sq.*) argues.

[3] See, besides the commentaries, Nöldeke in the *Bibel-lex.*, iv. 214; a paper by Oort and two by Kuenen in *Theol. Tijdsch.*, 1872; Wellhausen-Bleek, *Einleitung*, p. 426; Stade, *l.c.*, and *ibid.*, iii. 1 *sq.* Stade goes so far as to make the whole of Micah iv., v. presuppose the exile, and to find still later additions in iv. 5–10., v. 5, 6 [v. 4, 5]. Giesebrecht, *Theol. LZ.*, 1881, col. 443 *sq.*, rejects chap. iv. only. The arguments cannot be here cited at length, but they are tacitly kept in view in what follows.

these marks fit exactly the evil times of Manasseh as described in 2 Kings xxi. Chap. vii. 1–6, in which the public and private corruption of a hopeless age is bitterly bewailed, obviously belongs to the same context (comp. vol. xiii. p. 415). Micah may very well have lived into Manasseh's reign, but the title in i. 1 does not cover a prophecy which certainly falls after Hezekiah's death, and the style has nothing in common with the earlier part of the book. It is therefore prudent to regard the prophecy, with Ewald, as anonymous. Ewald ascribes the whole of chaps. vi., vii. to one author. Wellhausen, however, remarks with justice that the thread is abruptly broken at vii. 6, and that verses 7–20 represent Zion as already fallen before the heathen and her inhabitants as pining in the darkness of captivity. The hope of Zion is in future restoration after she has patiently borne the chastisement of her sins. Then Jehovah shall arise mindful of His oath to the fathers, Israel shall be forgiven and restored, and the heathen humbled. The faith and hope which breathe in this passage have the closest affinities with the book of Lamentations and Isa. xl.–lxvi.

We have seen that the text of Micah has suffered from redactors; it is also not free from verbal corruptions which make some places very obscure. The LXX. had many readings different from the present Hebrew, but their text too was far from sound. Of commentaries on Micah, that which deals most fully with the question of the text is Roorda's Latin work, Leyden, 1869. The most elaborate book on Micah is Caspari's (*Ueber Micha den Morasthiten und seine prophetische Schrift*, Christiania, 1851–52). In English Pocock's *Commentary* (2d ed., 1692) and Cheyne's *Micah* (1882) are to be noted. See also the literature on the minor prophets in general cited under HOSEA, and W. R. Smith's *Prophets of Israel* (1882). (W. R. S.)

MICHAEL (מִיכָאֵל, "who is like God?") appears in the Old Testament as a man's name, synonymous with Micaiah or Micah. In the book of Daniel the same name is given to one of the chief "princes" of the heavenly host, the guardian angel or "prince" of Israel (Dan. x. 13, 21; xii. 1), and as such he naturally appears in Jewish theosophy as the greatest of all angels, the first of the four who surround the throne of God (see GABRIEL). It is as guardian angel of Israel, or of the church, the true Israel, that Michael appears in Jude 9 and Rev. xii. 7. In the Western Church the festival of St Michael and All Angels (Michaelmas) is celebrated on September 29th; it appears to have grown out of a local celebration of the dedication of a church of St Michael either at Mount Garganus in Apulia or at Rome, and was a great day by the beginning of the 9th century. The Greek Church dedicates November 8 to St Michael, St Gabriel, and All Angels.

MICHAEL, the name of several Byzantine emperors.

MICHAEL I. (Rhangabé) was an obscure nobleman who had married Procopia, the daughter of Nicephorus I., and been made master of the palace; his elevation to the throne was due to a revolutionary movement against his brother-in-law Stauracius, who reigned only two months after the death of Nicephorus on the battlefield (812). Elected as the tool of the bigoted orthodox party in the church, Michael diligently persecuted the Iconoclasts on the northern and eastern frontiers of the empire, but meanwhile allowed the Bulgarians to ravage a great part of Macedonia and Thrace; having at last taken the field in the spring of 813, he was defeated near Bersinikia, and Leo the Armenian was saluted emperor in his stead in the following summer. Michael, after having been compelled to become a monk, was permitted thenceforward to live unmolested in the island of Prote, where he died in 845.

MICHAEL II. (The Stammerer), a native of Amorium in Phrygia, was of humble origin, and began life as a private soldier, but rose by his talents and assiduity to the rank of general. He was one of those who had favoured the election to the throne of his old companion in arms Leo the Armenian in 813, but, detected in a conspiracy against the government of that emperor, had been sentenced to death in December 820; his partisans, however, succeeded in assassinating Leo on the morning of Christmas Day, and called Michael from the prison to the throne. The principal features of his reign (820–829) were a protracted struggle (of nearly three years) against his brother general, Thomas, who aimed at the throne, the conquest of Crete by the Saracens in 823, and the beginning of their attacks upon Sicily (827). Conciliatory on the whole in his policy towards the image worshippers (his own sympathies were iconoclastic), he incurred the wrath of the monks by entering into a second marriage with Euphrosyne, daughter of Constantine VI., who had previously taken the veil. He died in October 829, and was succeeded by Theophilus his son.

MICHAEL III. (The Drunkard) was the grandson of Michael the Stammerer, and succeeded his father Theophilus when only three years of age (842). Until his majority at the age of eighteen the affairs of the empire were managed by the empress-regent his mother Theodora; his education was shamefully neglected, and it was during this period that Michael formed the disgraceful personal habits which are indicated by his surname. In 861 Michael, together with his uncle Bardas, undertook an expedition against the Bulgarians, which resulted in the conversion of the Bulgarian king, who thenceforth bore the Christian name of Michael. The emperor had been less successful in the campaign which he led in person against Omar of Melitene in 860, but in 863 his uncle Petronas gained an important victory over the Saracens in Asia Minor. The year 865 was marked by the first appearance of the Russians in the Bosphorus. Michael was assassinated in his palace in 867 by Basilius the Macedonian, whom he had associated with himself in the empire in the previous year.

MICHAEL IV. (The Paphlagonian) owed his elevation to Zoe, daughter of Constantine IX., the last of the Macedonian dynasty; this princess was married to Romanus III., but becoming enamoured of Michael, her chamberlain, she poisoned her husband and married her attendant (1034). Michael, however, being of a weak character and subject to epileptic fits, possessed the supreme power only in name, and was a mere instrument in the hands of his brother, John the Eunuch, who had been first minister both of Constantine and Romanus. John's diplomacy was successful in keeping the Arabs in the archipelago and Egypt quiet for some time, and he was at last able to secure a victory for the imperial arms at Edessa in 1037. The attempt to recover Sicily in the following year with the help of the Normans was less prosperous, and in 1040 the island wholly ceased to be a Byzantine province. About the same time, the Bulgarians having overrun Macedonia and Thrace, and threatening Constantinople, the indolent and infirm emperor, to the surprise alike of friends and foes, put himself at the head of the army, and not only drove the enemy beyond the frontier, but followed them into their own territory. He died, shortly after his triumph, on December 10, 1041.

MICHAEL V. (Calaphates or The Caulker), nephew and successor of the preceding, derived his surname from his father Stephen, who had originally followed the occupation of a caulker of ships. He owed his elevation (December 1041) to his uncle John, whom along with Zoe he almost immediately banished; this led to a popular tumult and his dethronement after a brief reign of four months (April 1042). He lived for many years afterwards in the quiet obscurity of a monastery.

MICHAEL VI. (The Warlike) was already an old man when chosen by the empress Theodora as her successor shortly before her death in 1056. His government was feeble in the extreme, and he was at last compelled to abdicate by Isaac Comnenus, who had defeated his army in Phrygia (August 1057). He also spent the rest of his life in a monastery.

MICHAEL VII. (Ducas or Parapinaces) was the eldest son of Constantine XI. Ducas, by whom along with his brothers Andronicus I. and Constantine XII. he was invested with the title of Augustus; this joint succession took place in 1067, but in 1071 it suited the policy of the uncle Joannes Cæsar to make Michael sole emperor. For

this position Michael, whose "character was degraded, rather than ennobled, by the virtues of a monk and the learning of a sophist," was by no means fitted, and at length two generals of the name of Nicephorus, surnamed Bryennius and Botaniates, simultaneously rebelled against him in 1078; with hardly a struggle he resigned the purple and retired into a monastery, where he afterwards received the title of archbishop of Ephesus.

MICHAEL VIII. (Palæologus), born in 1234, was the son of Andronicus Palæologus Comnenus and Irene Angela the granddaughter of Alexius Angelus, emperor of Constantinople. At an early age he rose to distinction, and ultimately became commander of the French mercenaries in the employment of the emperors of Nicæa. A few days after the death of Theodore Lascaris II. in 1259, Michael, by the assassination of Muzalon (which he is believed but not proved to have encouraged), succeeded to the guardianship, shared with the patriarch Arsenius, of the young emperor John Lascaris, then a lad of only eight years. Afterwards invested with the title of "despot," he was finally proclaimed joint-emperor, and crowned alone at Nicæa on January 1, 1260. In the following year (July 1261) Constantinople fell into the hands of the Cæsar Alexius Strategopulus, and Michael, having got himself crowned anew in the church of St Sophia, caused his boy colleague to be blinded and sent into banishment. For this last act he was excommunicated by Arsenius, and the ban was not removed until six years afterwards (1268), on the accession of a new patriarch. In 1263 and 1264 respectively Michael, with the help of Urban IV., concluded peace with Villehardouin, prince of Achaia, and Michael, despot of Epirus, who had previously been incited by the pope to attack him; the friendly intervention had been secured by a promise on the emperor's part to help forward the reunion of the Eastern and Western churches. In 1269 Charles of Sicily, aided by John of Thessaly, again made war with the alleged purpose of restoring Baldwin to the throne of Constantinople, and pressed Michael so hard that ultimately, yielding to the importunities of Gregory X., he caused the deputies of the Eastern church to attend the council of Lyons (1274) and there accept the "filioque" and papal supremacy. The union thus brought about between the two churches was, however, extremely distasteful to the Greeks, and the persecution of his "schismatic" subjects to which the emperor was compelled to resort weakened his power so much that Martin IV. was tempted to enter into alliance with Charles of Anjou and the Venetians for the purpose of reconquering Constantinople. The invasion, however, failed, and Michael so far had his revenge in the "Sicilian Vespers," which he helped to bring about. He died in Thrace in December 1282, and was succeeded by his son Andronicus II.

MICHAEL IX. (Palæologus) was the son of Andronicus II., and was associated with him on the throne from 1295, but predeceased him (1320).

MICHAELIS, JOHANN DAVID (1717–1791), one of the most influential scholars and teachers of last century, belonged to a family which had the chief part in maintaining that solid discipline in Hebrew and the cognate languages which distinguished the university of Halle in the period of Pietism. Johann Heinrich Michaelis (1668–1738) was the chief director of Francke's *Collegium Orientale Theologicum*, a practical school of Biblical and Oriental philology then quite unique, and the author of an annotated Hebrew Bible and various exegetical works of reputation, especially the *Adnotationes uberiores in Hagiographos*, 1720. In his chief publications J. H. Michaelis had as fellow-worker his sister's son Christian Benedict Michaelis (1680–1764), the father of Johann David, who was likewise influential as professor at Halle, and a very sound scholar, especially in Syriac. J. D. Michaelis was trained for academical life under his father's eye. Halle was not then the best of universities; a narrow theological spirit cramped all intellectual activity, and the eager vivacious youth, already distinguished by a love for realities and a distaste for small pedantries, found much of the teaching wearisome enough. He acquired, however, a good knowledge of the Latin classics,—Greek, he tells us, was hardly taught at all, and his knowledge of Greek literature was gained by his own reading in later years,—learned all that his father could teach, and was influenced, especially in philosophy, by Baumgarten, the link between the old Pietism and Semler, while he cultivated his strong taste for history under Ludwig. In the winter-semester 1739–40 he qualified as university lecturer. One of his dissertations was a defence of the antiquity and divine authority of the vowel points in Hebrew. His scholarship still moved in the old traditional lines in which no further progress was possible, and he was also much exercised by religious scruples, the conflict of an independent mind with that submission to authority at the expense of reason encouraged by the type of Lutheranism in which he had been trained. A long visit to England in 1741–42 lifted him out of the narrow groove of his earlier education. In passing through Holland he made the acquaintance of the great Schultens, whose influence on his philological views was not immediate, but became all-powerful a few years later. England offered to him no such commanding personal influence, and he was not yet able to turn to profit the stores of the great libraries, but his personality was strengthened by contact with a larger life, and his theological views were turned aside from the pietistic channel. Michaelis never ceased to regard himself as essentially orthodox, though he did not feel able fully to subscribe the Lutheran articles, and more than once declined on this account to be professor of theology. But his views acquired a distinctly rationalistic complexion, and the orthodoxy of his Göttingen lectures and publications on dogmatic (delivered from a philosophical chair) is of a very washed-out kind. His really useful work, however, lay in other directions; the change of his theological views was important because it relieved him from trammels that hampered the free course of his development as a scholar. From England Michaelis went back to Halle; but he felt himself out of place, and in 1745 gladly accepted an invitation to Göttingen as privat-docent. In 1746 he became extraordinary, in 1750 ordinary, professor, and in Göttingen he remained till his death in 1791. In the first years of his new position Michaelis passed through a second education. In the young and intellectually vigorous Georgia Augusta he came under the powerful personal influence of such men as Gesner and Haller. His intellect was active in many directions; universal learning indeed was perhaps one of his foibles. Literature—modern as well as ancient—occupied his attention; one of his works was a translation of four parts of *Clarissa*; and translations of some of the then current English paraphrases on Biblical books manifested his sympathy with a school which, if not very learned, attracted him by its freer air. His Oriental studies were reshaped by diligent perusal of the works of Schultens; for the Halle school, with all its learning, had no conception of the principles on which a fruitful connexion between Biblical and Oriental learning can be established. His linguistic work indeed was always hampered by the lack of MS. material which is felt in his philological writings, *e.g.*, in his valuable *Supplementa* to the Hebrew lexicons (1784–92).[1] He could not become

[1] By a strange fortune of war it was the occupation of Gottingen by the French in the Seven Years' War, and the friendly relations he

such an Arabist as Reiske; and, though for many years the most famous teacher of Semitic languages in Europe, he had little of the higher philological faculty, and neither his grammatical nor his critical work, highly praised as it then was, has left a permanent mark, with the exception perhaps of his text-critical studies on the Peshito.[1] His tastes were all for *realia*—history, antiquities, especially geography and natural science; in his autobiography he half regrets that he did not choose the medical profession. Here he found a field hardly touched since Bochart, in whose footsteps he followed in the *Spicilegium geographiæ Hebræorum exteræ post Bochartum* (1769–80). To his impulse we owe the famous Eastern expedition of Von Haven, Forskål, and Niebuhr. He prepared the instructions for their journey, and drew up a series of questions and elucidations to guide their researches, which place in strong relief his comprehensive grasp of all that was then known of the East, and the keen delight in the knowledge of tangible and natural things, paired with a sober and patient judgment, which was his chief intellectual characteristic. The best part of this knowledge was turned to the profit of Biblical study; in his exegetical writings, for example, one of the main features is what was then the novelty of illustrations from Eastern travel. In spite of his doctrinal writings—which at the time made no little noise, so that his *Compendium of Dogmatic* (1760) was confiscated in Sweden, and the knighthood of the North Star was afterwards given him in reparation—it was the natural side of the Bible that really attracted him, and no man did more to introduce the modern method of studying Hebrew antiquity as an integral part of ancient Eastern life. The permanent influence of his works indeed has not been great, and many of them are now hardly readable; for, with all his historic tastes and learning, he had no large historic conceptions, and, what is closely akin to this defect, was singularly deficient in imagination and poetic sympathy. But the vivacity of his mind, his manysidedness, his singularly attractive though discursive method of lecturing, and above all his power of feeling and inspiring interest in every kind of fact, was a potent stimulus much needed in the Germany of that age, and did not soon die. Different as the three men are, there is a true historic nexus between the three great Göttingen Orientalists, Michaelis, Eichhorn, and Ewald.

The personal character of Michaelis can be read between the lines of his autobiography with the aid of the other materials collected by the editor Hassencamp (*J. D. Michaelis Lebensbeschreibung*, &c., 1793). To understand the secret of his enormous influence, it is not enough to read his books, now for the most part dull enough to us; we must see the upright vivacious laborious man, with a good deal of worldly prudence and a good deal of temper, much absorbed in his manifold academic activities in the university and Royal Society of Göttingen, yet ever full of interest in the larger world, and of shrewd judgments and lively talk, with a strong sense of his rights and dignity, yet with a good and warm heart; shining especially in the lecture-room, where he dealt forth knowledge with discursive hand from a full store, displaying the methods as well as the results of his all-sided research, not without a touch of the vanity of the polyhistor, and loving to leave the chair under a storm of applause at a parting bon-mot which he acknowledged at the door in a backward glance of triumph. The same volume contains a full list of his works. Besides those already mentioned it is sufficient to refer to his New Testament *Introduction* (the first edition, 1750, preceded the full development of his powers, and is a very different book from the later editions), his reprint of Lowth's *Prælectiones* with important additions (1758–62), his German translation of the Bible with notes (1773–92), his *Orientalische und Exegetische Bibliothek* (1775–85), and *Neue O. and E. Bib.* (1786–91), his *Mosaisches Recht* (1770–71), and his edition of Castle's *Lexicon Syriacum* (1787–88). His *Litterarischer Briefwechsel* (1794–96) contains much that is interesting for the history of learning in his time. (W. R. S.)

formed with the officers, that procured him the Paris MS. from which he edited Abulfeda's description of Egypt.

[1] *Curæ in Actus Apostolorum Syriacos*, 1755.

MICHAUD, Joseph (1767–1839), French historian and publicist, was born of an old family on June 19, 1767, at Albens, Savoy, was educated at Bourg-en-Bresse, and afterwards engaged in literary work at Lyons, where the events of 1789 first called into activity the dislike to revolutionary principles which manifested itself throughout the rest of his life. In 1791 he went to Paris, where, not without danger, he took part in editing several royalist journals. In 1794 he started *La Quotidienne*, for his connexion with which he was arrested after the 13th of Vendémiaire; he succeeded in escaping his captors, but was sentenced to death *par contumace* by the military council. Having resumed the editorship of his newspaper on the establishment of the Directory, he was again proscribed on the 18th of Fructidor, but at the close of two years returned to Paris when the consulate had superseded the Directory. His Bourbon sympathies led to a brief imprisonment in 1800, and on his release he for the time abandoned journalism, and began to write or edit books. Along with his brother and two colleagues he published in 1806 a *Biographie moderne, ou dictionnaire des hommes qui se sont fait un nom en Europe depuis* 1789, the earliest work of its kind; in 1808 the first volume of his *Histoire des Croisades* appeared, and in 1811 he originated the *Biographie Universelle*. In 1814 he resumed the editorship of the *Quotidienne*, and in the same year was elected Academician. In 1815 his brochure entitled *Histoire des quinze Semaines ou le dernier règne de Bonaparte* met with extraordinary success, passing through twenty-seven editions within a very short time. His political services were now rewarded with the cross of an officer in the Legion of Honour and the modest post of king's reader, of which last he was deprived in 1827 for having opposed Peyronnet's "Loi d'Amour" against the freedom of the press. In 1830–31 he travelled in Syria and Egypt for the purpose of collecting additional materials for the *Histoire des Croisades*; his correspondence with a fellow explorer, Poujoulat, consisting practically of discussions and elucidations of various important points in that work, was afterwards published (*Correspondance d'Orient*, 7 vols., 1832–35). The *Bibliothèque des Croisades*, in four volumes more, contained the "pièces justificatives" of the *Histoire*. Michaud died on September 30, 1839, at Passy, where his home had been since 1832. His *Histoire des Croisades* was published in its final form in six volumes in 1841 under the editorship of his friend Poujoulat (9th ed., with appendix, by Huillard-Bréholles, 1856). Michaud along with Poujoulat also edited and in part wrote *Nouvelle Collection des Mémoires pour servir à l'Histoire de France*, 32 vols., 1836–44. See Sainte-Beuve, *Causeries du Lundi*, vol. vii.

MICHAUX, André (1746–1802), a French botanist, best known for his works on the flora of North America and as a botanical traveller. In 1779 he spent some time botanizing in England, and in 1780 he explored Auvergne, the Pyrenees, and the north of Spain. In 1782 he was sent by the French Government on a botanical mission to Persia. His journey began unfavourably, as he was robbed by Arabs of all his equipments except his books; but he gained influential support in Persia, having cured the shah of a dangerous illness. After two years he returned to France with a fine herbarium, and also introduced numerous Eastern plants into the botanic gardens of France. In 1785 he was sent by the French Government to North America, and travelled through Canada, Nova Scotia, and the United States as far west as the Mississippi. The outbreak of the French Revolution deprived him of means to continue his work in America, and in 1796 he returned to France. He was shipwrecked, and lost most of his collections on the voyage. In 1800

he went to Madagascar to investigate the flora of that island, and died there in 1802. His work as a botanist was chiefly done in the field, and he added largely to what was previously known of the botany of the East and of America. He also introduced many plants into European botanic gardens. He wrote two valuable works on North-American plants,—the *Histoire des chênes de l'Amérique Septentrionale* (1801), with 36 plates, and the *Flora Boreali-Americana* (1803), 2 vols., with 51 plates.

MICHAUX, François André (1770–1855), son of the preceding, was, like his father, employed by the French Government to explore the forests of North America with a view to the introduction into France of trees valuable for their wood or other products. He was very successful in carrying out this object. He published in 1810–13 a *Histoire des Arbres forestières de l'Amérique Septentrionale*, in 3 vols., with 156 plates, a work full of information on the characters, uses, distribution, and other points of interest in the various species. In 1817–19 a translation of it appeared under the title *North American Sylva.* He also wrote a *Voyage a l'ouest des Monts Alléghanys*, 1804, besides articles in scientific magazines.

MICHELANGELO (1475–1564). Michelangelo Buonarroti, best known simply as Michelangelo, the last and most famous of the great artists of Florence, was the son of Ludovico Buonarroti, a poor gentleman of that city, and of his wife Francesca di Neri. Ludovico was barely able to live on the income of his estate, but made it his boast that he had never stooped to add to it by mercantile or mechanical pursuits. The favour of the Medici procured him employment in some minor offices of state, and in the autumn of 1474 he was appointed resident magistrate of Caprese, in the Casentino, for a period of six months. Thither he accordingly repaired with his family, and there, on March 6, 1475, his second son Michelagniolo or Michelangelo was born. Immediately afterwards the family returned to Florence, and the child was put to nurse with a marble-worker's wife of Settignano. His mother's health had already, it would seem, begun to fail; at all events in about two years from this time, after she had borne her husband two more sons, she died. While still a young boy, Michelangelo determined in spite of his father's opposition to be an artist. He had sucked in the passion, as he himself used to say, with his foster-mother's milk. After a sharp struggle, his stubborn will overcame his father's pride of gentility, and at thirteen he got himself articled as a paid assistant in the workshop of the brothers Ghirlandaio. Domenico Ghirlandaio, bred a jeweller, had become by this time the foremost painter of Florence. In his service the young Michelangelo laid the foundations of that skill in fresco with which twenty years afterwards he confounded his detractors at Rome. He studied also, like all the Florentine artists of that age, in the Brancacci chapel, where the frescos of Masaccio, painted some sixty years before, still victoriously held their own; and here, in a quarrel with an ill-conditioned fellow-student, Torrigiani, he received the blow of which his face bore the marks to his dying day.

Though Michelangelo's earliest studies were directed towards painting, he was by nature and predilection much more inclined to sculpture. In that art he presently received encouragement and training under the eye of an illustrious patron, Lorenzo dei Medici. On the recommendation, it is said, of Ghirlandaio, he was transferred, before the term of his apprenticeship as a painter had expired, to the school of sculpture established by Lorenzo in the Medici gardens. Here he could learn to match himself against his great predecessor, Donatello, one of whose pupils was the director of the school, and to compare the works of that master and his Tuscan contemporaries with the antiques collected for the instruction of the scholars. Here, too, he could listen to discourses on Platonism, and steep himself in the doctrines of an enthusiastic philosophy which sought to reconcile with Christian faith the lore and the doctrines of the Academy. Michelangelo remained a Christian Platonist to the end of his days; he was also from his youth up a devoted student of Dante. His powers of mind and hand soon attracted attention, and secured him the regard and favour of his patrons in spite of his rugged, unsociable exterior, and of a temper which at best was but a half-smothered volcano.

Michelangelo had been attached to the school and household of the Medici for barely three years when, in 1492, his great patron Lorenzo died. Lorenzo's son Piero dei Medici inherited the position, but not the qualities, of his father; Florence soon chafed under his authority; and towards the autumn of 1494 it became apparent that disaster was impending over him and his adherents. Michelangelo was constitutionally subject to dark and sudden presentiments: one such seized him now, and, without awaiting the popular outbreak which soon followed, he took horse with two companions and fled to Bologna. There, being now in his twentieth year, he was received with kindness by a member of the Aldovrandi family, and on his commission executed two figures of saints, and one of an angel, for the shrine of St Dominic in the church of St Petronius. After about a year, work at Bologna failing, and his name having been included in his absence on the list of artists appointed to provide a new hall of assembly for the Great Council of Florence, Michelangelo returned home. The strange theocracy established by Savonarola was now in force, and the whole character of civic life at Florence was for the time being changed. But Michelangelo was not left without employment. He found a friend in another Lorenzo, the son of Pierfrancesco dei Medici, for whom he at this time executed a statue of the boy St John. Having also carved a recumbent Cupid in imitation of the antique, it was suggested to him by the same patron that it should be so tinted and treated as to look like a real antique, and sold accordingly. Without increasing the price he put upon the work, Michelangelo for amusement lent himself to the counterfeit, and the piece was then actually sold for a large sum to a Roman collector, the cardinal San Giorgio, as a genuine work of antiquity,—the dealer appropriating the profits. When presently the cardinal discovered the fraud, he caused the dealer to refund; but as to Michelangelo himself, it was represented to the young sculptor that if he went to Rome, the amateur who had just involuntarily paid so high a tribute to his skill would certainly befriend him. He set forth accordingly, and arrived at Rome for the first time at the end of June 1496. Such hopes as he may have entertained of countenance from the cardinal San Giorgio were quickly dispelled. Neither did the banished Piero dei Medici, who also was now living at Rome, do anything to help him. On the other hand Michelangelo won the favour of a Roman nobleman, Jacopo Galli, and through him of the French cardinal Jean de Villiers de la Grolaie, abbot of St Denis. From the former he received a commission for a Cupid and a Bacchus, from the latter for a *Pietà*, or Mary lamenting over the body of Christ,—works of which probably all three, the last two certainly, are preserved.

Michelangelo's stay in Rome at this time lasted five years, from the summer of 1496 till that of 1501. The interval had been one of extreme political distraction at Florence. The excitement of the French invasion, the mystic and ascetic regimen of Savonarola, the reaction which led to his overthrow, and finally the external wars and internal dissidences which preceded a new settlement, had all created an atmosphere most unfavourable to art.

Nevertheless Ludovico Buonarroti, who in the troubles of 1494 had lost a small permanent appointment he held in the customs, and had come to regard his son Michelangelo as the mainstay of his house, had been repeatedly urging him to come home.

A spirit of family duty and family pride was the ruling principle in all Michelangelo's conduct. During the best years of his life he submitted himself sternly and without a murmur to pinching hardship and almost superhuman labour for the sake of his father and brothers, who were ever selfishly ready to be fed and helped by him. Having now, after an illness, come home in 1501, Michelangelo received the request from the cardinal Francesco Piccolomini to adorn with a number of sculptured figures a shrine already begun in the cathedral of Siena in honour of the most distinguished member of his house, Pope Pius II. Four only of these figures were ever executed, and those not apparently, or only in small part, by the master's hand. A work of greater interest in Florence itself had diverted him from his engagement to his Sienese patron. This was the execution of the famous colossal statue of David, popularly known as the Giant. It was carved out of a huge block of marble on which another sculptor, Agostino d'Antonio, had begun unsuccessfully to work forty years before, and which had been lying idle ever since. Michelangelo had here a difficult problem before him. Without much regard to tradition or the historical character of his hero, he carved out of the vast but cramped mass of material a youthful, frowning colossus, which amazed every beholder by its freedom and science of execution, and its victorious energy of expression. All the best artists of Florence were called in council to determine on what site it should be set up, and after much debate the terrace of the Palace of the Signory was chosen, in preference to the neighbouring Loggia dei Lanzi. Here accordingly the colossal David of Michelangelo took, in the month of May 1504, the place which it continued to hold ever afterwards, until ten years ago, in 1873, it was removed for the sake of protection to a hall in the Academy of Fine Arts. Other works of sculpture by the same indomitable hand also belong to this period: among these another David, in bronze, and on a smaller scale; a great rough-hewn St Matthew begun but never completed for the cathedral of Florence; a Madonna and Child executed on the commission of a merchant of Bruges; and two unfinished bas-reliefs of the same subject.

Neither was Michelangelo idle at the same time as a painter. Leaving disputed works for the moment out of sight, he in these days at any rate painted for his and Raphael's common patron, Angelo Doni, the Holy Family now in the Uffizi at Florence. And in the autumn of 1504, the year of the completion of the David, he received from the Florentine state a commission for a work of monumental painting on an heroic scale. Leonardo da Vinci had been for some months engaged on his great cartoon of the Battle of Anghiari, to be painted on the wall of the great hall of the municipal council. The gonfaloniere Soderini now procured for Michelangelo the commission to design a companion work. Michelangelo chose an incident of the Pisan war, when the Florentine soldiery had been surprised by the enemy in the act of bathing: he dashed at the task with his accustomed fiery energy, and had carried a great part of the cartoon to completion when, in the early spring of 1505, he broke off the work in order to obey a call to Rome which reached him from Pope Julius II. His unfinished cartoon showed how greatly Michelangelo had profited by the example of his elder rival, Leonardo, little as, personally, he yielded to his charm or could bring himself to respond to his courtesy. The work of Michelangelo's youth is for the most part comparatively tranquil in character. His early sculpture, showing a degree of science and perfection unequalled since the antique, has also something of the antique serenity. It bears strongly the stamp of intellectual research, but not by any means that of storm or strain. In the cartoon of the Bathers, he on the other hand appropriated and carried further the mastery, which Leonardo had first asserted, over every variety of violent action and every extreme of energetic movement. In it the qualities afterwards proverbially associated with Michelangelo—his *furia*, his *terribilità*, the tempest and hurricane of the spirit which accompanied his unequalled technical mastery and knowledge—first found expression.

With Michelangelo's departure to Rome early in 1505 the first part of his artistic career may be said to end. It will be convenient here to recapitulate its principal results in sculpture and painting, both those preserved, and those recorded but lost.

SCULPTURE.—Florence, 1489–94. *Head of a Faun*, National Museum, Florence (?). Condivi describes Michelangelo's first essay in sculpture as a head of an aged faun with a front tooth knocked out, this latter point having been an afterthought suggested by Lorenzo dei Medici. The head is commonly identified with one in the National Museum at Florence, which, however, bears no marks of Michelangelo's style, and is in all probability spurious. *Madonna Seated on a Step*, Casa Buonarroti, Florence. This bas-relief is a genuine example of Michelangelo's early work in the Medicean school under Bertoldo. It is executed in low relief in imitation of the technical style of Donatello; but the attitudes and characters of the figures, and the long-drawn, somewhat tormented folds of drapery, recall rather the manner of Jacopo della Quercia. *Centauromachia*, Casa Buonarroti. A fine and unquestionably genuine work in full relief, of probably somewhat later date than the last-mentioned; Michelangelo has followed the antique in his conception and treatment of the nude, but not at all in the arrangement of the subject, which occurs frequently in works of ancient art.

Bologna, 1494–95. *Kneeling Angel*, supporting the shrine of St Dominic. This is the figure, with crisp hair, short resolute features, and drapery clinging to show the limbs, on the right-hand side of the spectator as he fronts the altar. The prettier and more engaging figure at the opposite end was long taken to be Michelangelo's work, but is really that of Niccolò dell' Arca. Michelangelo also finished the figure of St Petronius on the cornice of the same altar, begun by the same Niccolò, and executed one of St Proculus which has perished.

Florence, 1495–96. *St John in the Wilderness*, Berlin Museum. During the year between Michelangelo's return from Bologna and his first departure to Rome he executed, as has been narrated above, a statue of S. Giovannino for Lorenzo di Pierfrancesco dei Medici. This had for centuries been supposed lost, when in 1874 it was declared to have been found in the possession of Count Gualandi-Rossalmini at Pisa. Vehement and prolonged discussions arose as to the authenticity of the work, and at last it was bought for the Berlin Museum, where its genuineness is with apparently good reason maintained. The stripling saint stands naked but for a skin about his loins, holding a honeycomb in his left hand and lifting to his mouth a goat's horn full of honey with his right. *Restoration of an antique group of Bacchus and Ampelus*, Uffizi Gallery, Florence. This interesting restoration of an antique torso, by the addition of a head, the lower part of the legs, and the accessory figure of an attendant genius, a plinth, and mask, is not one of the works traditionally ascribed to Michelangelo; but has lately, and as it seems rightly, been claimed for him on internal evidence. *Recumbent Cupid*, bought by the cardinal San Giorgio as an antique. This work, which played an important part in Michelangelo's history, is unfortunately lost.

Rome, 1495–1501. *Kneeling Cupid*, South Kensington Museum, London. This beautiful statue of an athletic youth kneeling on the right knee, looking over his right shoulder, with the right hand lowered and the left raised, and having a quiver on the ground beside him, is acknowledged on internal grounds as an early work of Michelangelo. There is some ambiguity about the character and action of the personage; but the work is usually identified with the Cupid which Michelangelo is recorded to have executed at this time for Jacopo Galli. *Bacchus and Young Faun*, National Museum, Florence. This is unquestionably the "Bacchus" commissioned by the same patron. The finely-framed but soft-limbed youthful god, his weight supported somewhat staggeringly on the left leg, holds up a wine cup in his right hand, and with his loosely-hanging left hand holds a cluster of grapes, at which a child-faun standing a little behind him grasps and nibbles. The surface highly finished and polished, as in the Berlin St John. *Virgin Lamenting the Dead Christ*, St Peter's, Rome. This group, executed for the French abbot of St Denis, is the finest of all

Michelangelo's early sculptures, and one of the finest of his life. It still recalls the ideals of some of the earlier Tuscan masters, especially Jacopo da Quercia; but the execution is of a mastery and nobility unprecedented in Italian art. The Virgin, in drapery of magnificent design, with her left knee somewhat raised and her right hand slightly extended, sits holding on her lap the dead Christ,—a figure of splendid frame and modelling as well as of admirable pathos and dignity in expression.

Florence, 1501–6. *Four Saints decorating the Shrine of Pius II.*, in the cathedral of Siena. These figures represent the only part which Michelangelo ever completed of his contract with the cardinal Piccolomini and his heirs. They are evidently carried out by the hand of pupils only. *Virgin and Child*, Liebfrauenkirche, Bruges. This pleasing group has been since the days of Albert Dürer attributed to Michelangelo, and bears the manifest stamp of his design, though its execution may be partly by inferior hands. It is placed close to the tombstone of a member of the Moscheroni (or Moskeron) family. We know that Michelangelo executed at this time, for one of this very family, a work which the ancient biographers describe as having been in bronze,—a medallion in that metal, says explicitly Vasari; but it is probably really the marble group in question. *Virgin and Child*, Royal Academy, London. This beautiful unfinished circular relief is identified with one recorded to have been executed by the master for Taddeo Gaddi. *Virgin and Child*, National Museum, Florence,—a similar relief, also unfinished, originally ordered by Bartolommeo Pitti. *Youthful David*, Academy of Arts, Florence. Of this colossal work, which in spite of its scale and subject has still, in grace of pose and style, a considerable artistic affinity with the earlier Bacchus and St John, enough has been said. *Figure of David*, a small statue in bronze. Several extant works have been pointed out as probably identical with this lost statue; but the claims of none have been generally acknowledged.

PAINTING.—*Holy Family*, Uffizi, Florence. This circular picture, painted for Angelo Doni, and mentioned by the earliest biographers, is the only perfectly well-attested panel-painting of Michelangelo which exists. His love of restless and somewhat strained actions is illustrated by the action of the Madonna, who kneels on the ground holding up the child on her right shoulder; his love of the nude by the introduction (wherein he follows Luca Signorelli) of some otherwise purposeless undraped figures in the background. *Virgin and Child with Four Angels*, National Gallery, London. This unfinished painting, marked by great grace as well as severity of feeling and design, was formerly attributed to Domenico Ghirlandaio, but is now commonly held to be the earliest extant picture by Michelangelo. Of his manner, especially in the design and treatment of the drapery, it bears evident marks; but the execution seems like that of some weaker pupil or companion, perhaps Ridolfo Ghirlandaio or Granacci. *Entombment of Christ*, National Gallery, London. This picture, also unfinished, has in like manner been much contested. Its composition is unfortunate; weaker hands have disfigured some portions of the work; but the extraordinary excellence of other portions, and the grandeur of some of the actions, render it probable that the work is one begun and afterwards abandoned by Michelangelo himself. *Cartoon of the Battle of Anghiari*. Of this famous lost work (begun, though apparently not completed, in the period now engaging us) the only authentic record is contained in two early engravings, one by Marcantonio and the other by Agostino Veneziano. An elaborate drawing of many figures at Holkham Hall, well known and often engraved, seems to be a later *cento* destitute of real authority.

Michelangelo had not been long in Rome before Pope Julius devised fit employment for him. That capacious and headstrong spirit, on fire with great enterprises, had conceived the idea of a sepulchral monument to commemorate his glory when he should be dead, and to be executed according to his own plans while he was still living. He entrusted this congenial task to Michelangelo. The design being approved, the artist spent the winter of 1505–6 at the quarries of Carrara, superintending the excavation and shipment of the necessary marbles. In the spring he returned to Rome, and when the marbles arrived fell to with all his energy at the preparations for the work. For a while the pope followed their progress eagerly, and was all kindness to the young sculptor. But presently his disposition changed. In Michelangelo's absence an artist who was no friend of his, Bramante of Urbino, had been selected by Julius to carry out a new architectural scheme, commensurate with the usual vastness of his conceptions, namely the rebuilding of St Peter's church. To the influence and the malice of Bramante Michelangelo attributed the unwelcome invitation he now received to interrupt the great work of sculpture which he had just begun, in order to decorate the Sixtine chapel with frescos. Soon, however, schemes of war and conquest interposed to divert the thoughts of Julius, not from the progress of his own monument merely, but from artistic enterprises altogether. One day Michelangelo heard him say at table to his jeweller that he meant to spend no more money on pebbles either small or great. To add to the artist's discomfiture, when he went to apply in person for payments due, he was first put off from day to day, and at last actually with scant courtesy dismissed. At this his dark mood got the mastery of him. Convinced that not his employment only but his life was threatened, he suddenly took horse and left Rome, and before the messengers of the pope could overtake him was safe on Florentine territory. Michelangelo's flight took place in April 1506. Once among his own people, he turned a deaf ear to all overtures made from Rome for his return, and stayed throughout the summer at Florence, how occupied we are not distinctly informed, but apparently, among other things, on the continuation of his great battle cartoon.

During the same summer Julius planned and executed the victorious military campaign which ended in his unopposed entry at the head of his army into Bologna. Thither, under strict safe-conduct and promises of renewed favour, Michelangelo was at last prevailed on to betake himself. Julius received the truant artist kindly, as indeed between these two volcanic natures there existed a natural affinity, and ordered of him his own colossal likeness in bronze, to be set up, as a symbol of his conquering authority, over the principal entrance of the church of St Petronius. For the next fifteen months Michelangelo devoted his whole strength to this new task. The price at which he undertook it left him, as it turned out, hardly any margin to subsist on. Moreover, in the technical art of metal casting he was inexperienced, and an assistant whom he had summoned from Florence proved insubordinate and had to be dismissed. Nevertheless his genius prevailed over every hardship and difficulty, and on the 21st of February 1508 the majestic bronze colossus of the seated pope, robed and mitred, with one hand grasping the keys and the other extended in a gesture of benediction and command, was duly raised to its station over the church porch. Three years later it was destroyed in a revolution. The people of Bologna rose against the authority of Julius; his delegates and partisans were cast out, and his effigy hurled from its place. The work of Michelangelo, after being trailed in derision through the streets, was broken up and its fragments cast into the furnace.

Meanwhile the artist himself, as soon as his work was done, had followed his reconciled master back to Rome. The task that here awaited him, however, was after all not the resumption of the papal monument, but the execution of the series of paintings in the Sixtine chapel which had been mooted before his departure. Painting, he always averred, was not his business; and he entered with misgiving and reluctance upon his new undertaking. Destiny, however, so ruled that the work thus thrust upon him remains his chief title to glory. His history is one of indomitable will and almost superhuman energy, yet of will that hardly ever had its way, and of energy continually at war with circumstance. The only work which in all his life he was able to complete as he had conceived it was this of the decoration of the Sixtine ceiling. The pope had at first proposed a scheme including figures of the twelve apostles only. Michelangelo would be content with nought so meagre, and furnished instead a design of many hundred figures, embodying all the history of creation and

of the first patriarchs, with accessory personages of prophets and sibyls dreaming on the new dispensation to come, and, in addition, those of the forefathers of Christ. The whole was to be enclosed and divided by an elaborate framework of painted architecture, with a multitude of nameless human shapes supporting its several members or reposing among them,—shapes mediating, as it were, between the features of the inanimate framework and those of the great dramatic and prophetic scenes themselves. Michelangelo's plan was accepted by the pope, and by May 1508 his preparations for its execution were made. Later in the same year he summoned a number of assistant painters from Florence. Trained in the traditions of the earlier Florentine school, they were unable, it seems, to interpret Michelangelo's designs in fresco either with sufficient freedom or sufficient uniformity of style to satisfy him. At any rate he soon dismissed them, and carried out the remainder of his colossal task alone, except for the necessary amount of purely mechanical and subordinate help. The physical conditions of prolonged work, face upwards, upon this vast expanse of ceiling were adverse and trying in the extreme. But after four and a half years of toil the task was accomplished. Michelangelo had during its progress been harassed alike by delays of payment and by hostile intrigue. The absolute need of funds for the furtherance of the undertaking had even constrained him at one moment to break off work, and pursue his inconsiderate master as far as Bologna. His ill-wishers at the same time kept casting doubts on his capacity, and vaunting the superior powers of Raphael. That gentle spirit would by nature have been no man's enemy, but unluckily Michelangelo's moody, self-concentrated temper prevented the two artists being on terms of amity such as might have stopped the mouths of mischief-makers. Once during the progress of his task Michelangelo was compelled to remove a portion of the scaffolding and exhibit what had been so far done, when the effect alike upon friends and detractors was overwhelming. Still more complete was his triumph when, late in the autumn of 1512, the whole of his vast achievement was disclosed to view.

The main field of the Sixtine ceiling is divided into four larger alternating with five smaller fields. The following is the order of the subjects depicted in them:—(1) the dividing of the light from the darkness; (2) the creation of sun, moon, and stars, and of the herbage; (3) the creation of the waters; (4) the creation of man; (5) the creation of woman; (6) the temptation and expulsion; (7) an enigmatical scene, said to represent the sacrifice of Cain and Abel, but rather resembling the sacrifice of Noah; (8) the deluge; (9) the drunkenness of Noah. The figures in the last three of these scenes are on a smaller scale than those in the first six. In numbers 1, 3, 5, 7, and 9 the field of the picture is reduced by the encroachments of the architectural framework and supporters. These subjects are flanked at each end by the figure of a seated prophet or sibyl alternately; two other prophets are introduced at each extremity of the series, making seven prophets and five sibyls in all. In the angles to right and left of the prophets at the two extremities are the Death of Goliath, the Death of Judith, the Brazen Serpent, and the Punishment of Haman. In the twelve lunettes above the windows, and the similar number of triangular vaulted spaces over them, are mysterious groups, or pairs of groups, of figures, which from Michelangelo's own time have usually been known as Ancestors of Christ. The army of nameless architectural and subordinate figures is too numerous to be here spoken of. The work represents all the powers of Michelangelo at their best. Disdaining all the accessory allurements of the painter's art, he has concentrated himself upon the exclusive delineation of the human form and face at their highest power. His imagination has conceived, and his knowledge and certainty of hand have enabled him to realize, attitudes and combinations of unmatched variety and grandeur, and countenances of unmatched expressiveness and power. But he has not trusted, as he came later to trust, to science and acquired knowledge merely, neither do his personages, so far as they did afterwards, transcend human possibility or leave the facts of actual life behind them. In a word, his sublimity, often in excess of the occasion, is here no more than equal to it; moreover it is combined with the noblest elements of grace and even of tenderness. As for the intellectual meanings of his vast design, over and above those which reveal themselves at a first glance or by a bare description,—they are from the nature of the case inexhaustible, and can never be perfectly defined. Whatever the soul of this great Florentine, the spiritual heir of Dante, with the Christianity of the Middle Age not shaken in his mind, but expanded and transcendentalized, by the knowledge and love of Plato,—whatever the soul of such a man, full of suppressed tenderness and righteous indignation, and of anxious questionings of coming fate, could conceive, that Michelangelo has expressed or shadowed forth in this great and significant scheme of paintings. The details it must remain for every fresh student to interpret in his own manner.

The Sixtine chapel was no sooner completed than Michelangelo resumed work upon the marbles for the monument of Julius. But four months only had passed when Julius died. His heirs immediately entered (in the summer of 1513) into a new contract with Michelangelo for the execution of the monument on a reduced scale. What the precise nature and extent of the original design had been we do not know, but the new one was extensive and magnificent enough. It was to consist of a great quadrilateral structure, two courses high, projecting from the church wall, and decorated on its three unattached sides with statues. On the upper course was to be placed the colossal recumbent figure of the pope under a canopy, and beside it mourning angels, with prophetic and allegoric personages at the angles,—sixteen figures in all. The lower course was to be enriched with twenty-four figures in niches and on projecting pedestals:—in the niches, Victories trampling on conquered Provinces; in the pedestals, Arts and Sciences in bondage. The entire work was to be completed in nine years' time. During the next three years, it would seem, Michelangelo brought to completion three at least of the promised figures, and they are among the most famous of all existing works of the sculptor's art,—namely, the Moses now in the church of S. Pietro in Vincoli at Rome and the two "Slaves" at the Louvre.

The Moses, originally intended for one of the angles of the upper course, is now placed at the level of the eye, in the centre of the principal face of the monument as it was at last finished, on a deplorably reduced and altered scale, by Michelangelo and his assistants in his old age. The prophet, heavily bearded and draped, with only his right arm bare, sits with his left foot drawn back, his head raised and turned to the left with an expression of indignation and menace, his left hand laid on his lap and his right grasping the tables of the law. The work, except in one or two places, is of the utmost finish, and the statue looks like one of the prophets of the Sixtine ceiling done in marble. The "Slaves" at the Louvre are youthful male figures of equally perfect execution, nude but for the band which passes over the breast of one and the right leg of the other. One, with his left hand raised to his head and his right pressed to his bosom, and his eyes almost closed, seems succumbing to the agonies of death; the other, with his arms bound behind his back, looks upward still hopelessly struggling. There is reason to believe that all three of these figures were finished between 1513 and 1516. The beginnings of other figures or groups intended for the same monument are to be found at Florence, where they were no doubt made and then abandoned some years later,—viz., four rudely blocked figures of slaves or prisoners, in a grotto of the Boboli gardens, and the so-called Victory in the National Museum, an unfinished group of a combatant kneeling on and crushing to death a fallen enemy; with these may be associated a wax model known as Hercules and Cacus in the South Kensington Museum, and the figure of a crouching man at St Petersburg.

By this time (1516) Michelangelo's evil star was again in the ascendant. Julius II. had been succeeded on the papal throne by a Medici under the title of Leo X. The Medici, too, had about the same time by force and fraud re-established their sway in Florence, overthrowing the free institutions that had prevailed there since the days of Savonarola. Now on the one hand this family were the hereditary friends and patrons of Michelangelo; on the other hand he was a patriotic son of republican Florence; so that henceforward his personal allegiance and his political sympathies were destined to be at conflict. Over

much of his art, as has been thought, the pain and perplexity of this conflict have cast their shadow. For the present the consequence to him of the rise to power of the Medici was a fresh interruption of his cherished work on the tomb of Julius. Leo X. and his kinsmen insisted that Michelangelo, regardless of all other engagements, must design and carry out a great new scheme for the enrichment of their own family church of San Lorenzo in Florence. The heirs of Julius on their part showed an accommodating temper, and at the request of Leo allowed their three-years'-old contract to be cancelled in favour of another, whereby the scale and sculptured decorations of the Julian monument were again to be reduced by nearly a half. Unwillingly Michelangelo accepted the new commission thus thrust upon him for the church façade at Florence; but, having once accepted it, he produced a design of combined sculpture and architecture as splendid and ambitious in its way as had been that for the monument of Julius. In the summer of 1516 he left Rome for Carrara to superintend the excavation of the marbles.

Michelangelo was now in his forty-second year. Though more than half his life was yet to come, yet its best days had, as it proved, been spent. All the hindrances which he had encountered hitherto were as nothing to those which began to beset him now. For the supply of materials for the façade of San Lorenzo he had set a firm of masons to work, and had himself, it seems, entered into a kind of partnership with them, at Carrara, where he knew the quarries well, and where the industry was hereditary and well understood. When all was well in progress there under his own eye, reasons of state induced the Medici and the Florentine magistracy to bid him resort instead to certain new quarries at Pietrasanta, near Serravalle in the territory of Florence. Hither, to the disgust of his old clients at Carrara and to his own, Michelangelo accordingly had to transfer the scene of his labours. Presently he found himself so impeded and enraged by the mechanical difficulties of raising and transporting the marbles, and by the disloyalty and incompetence of those with whom he had to deal, that he was fain to throw up the commission altogether. The contracts for the façade of San Lorenzo were rescinded in March 1518, and the whole magnificent scheme came to nothing. Michelangelo then returned to Florence, where proposals of work poured in on him from many quarters. The king of France desired something from his hand to place beside the two pictures he possessed by Raphael. The authorities of Bologna wanted him to design a façade for their church of St Petronius; those of Genoa to cast a statue in bronze of their great commander, Andrea Doria. Cardinal Grimani begged hard for any picture or statue he might have to spare; other amateurs importuned him for so much as a pencil drawing or sketch. Lastly his friend and partisan Sebastian del Piombo at Rome, ever eager to keep up the feud between the followers of Michelangelo and those of Raphael, besought him on Raphael's death to return at once to Rome, and take out of the hands of the dead master's pupils the works of painting still remaining to be done in the Vatican chambers. Michelangelo complied with none of these requests. All that we know of his doing at this time was the finishing a commission received and first put in hand four years previously, for a full-sized statue of a nude Christ grasping the Cross. This statue, completed and sent to Rome in 1521 (with some last touches added by subordinate hands in Rome itself), stands now in the church of Sta Maria sopra Minerva; there is little in it of the Christian spirit as commonly understood, although, in those parts which Michelangelo himself finished, there is extreme accomplishment of design and workmanship.

The next twelve years of Michelangelo's life (1522–34) were spent at Florence, and again employed principally in the service of his capricious and uncongenial patrons, the Medici. The plan of a great group of monuments to deceased members of this family, to be set up in their mortuary chapel in San Lorenzo, seems to have been formed, and preparations to have been made by Michelangelo for its execution, as early as 1519. It was not, however, until 1524, after Leo X. had died, and his successor Adrian VI. had been in his turn succeeded by another Medicean pope, Clement VII., that any practical impulse was given to the work. Even then the impulse was a wavering one. First Clement proposed to associate another artist, Sansavino, with Michelangelo in his task. This proposal being on Michelangelo's peremptory demand abandoned, Clement next distracted the artist with an order for a new architectural design,—that, namely, for the proposed Medicean or "Laurentian" library. When at last the plans for the sepulchral monuments took shape, they did not include, as had been at first intended, memorials to the founders of the house's greatness, Cosimo and Lorenzo the Magnificent, or even to Pope Leo X. himself, but only to two younger members of the house lately deceased, Giuliano, duke of Nemours, and Lorenzo, duke of Urbino. Michelangelo brooded long over his designs for this work, and was still engaged on its execution—his time being partly also taken up by the building plans for the Medicean library—when political revolutions interposed to divert his industry. In 1527 came to pass the sack of Rome by the Austrians, and the apparently irretrievable ruin of Pope Clement. The Florentines seized the occasion to expel the Medici from their city, and set up a free republican government once more. Naturally no more funds for the work in San Lorenzo were forthcoming, and Michelangelo, on the invitation of the new signory, occupied himself for a while with designs for a colossal group of Samson and the Philistines, to be wrought out of a block of marble which had been rough-hewn already for another purpose by Baccio Bandinelli. Soon, however, he was called to help in defending the city itself from danger. Clement and his enemy Charles V. having become reconciled, both alike were now bent on bringing Florence again under the rule of the Medici. In view of the approaching siege, Michelangelo was appointed engineer-in-chief of the fortifications. He spent the early summer of 1529 in strengthening the defences of San Miniato; from July to September he was absent on a diplomatic mission to Ferrara and Venice. Returning in the middle of the latter month, he found the cause of Florence hopeless from internal treachery and from the overwhelming strength of her enemies. One of his dark seizures overcame him, and he departed again suddenly for Venice. Not cowardice, but despair of his city's liberties, and still more of his own professional prospects amid the turmoil of Italian affairs, was the motive of his departure. For a while he remained in Venice, negotiating for a future residence in France. Then, while the siege was still in progress, he returned once more to Florence; but in the final death-struggle of her liberties he bore no part. When in 1530 the city submitted to her conquerors, no mercy was shown to most of those who had taken part in her defence. Michelangelo believed himself in danger with the rest, but on the intervention of Baccio Valori he was presently taken back into favour and employment by Pope Clement. For three years more he still remained at Florence, engaged principally on the completion of the Medici monuments, and on the continuance of the Medicean library, but partly also on a picture of Leda for the duke of Ferrara.

The statues of the Medici monument take rank beside the Moses and the Slaves as the finest work of Michelangelo's central time in sculpture; moreover, though some of the figures are unfinished, they constitute as actually executed a complete scheme. They

consist of a Madonna and Child (left imperfect because the marble was short in bulk), and of the two famous monumental groups, each consisting of an armed and seated portrait-statue in a niche, with two emblematic figures reclining on each side of a sarcophagus below. The portraits are treated not realistically but typically. In that of Lorenzo seems to be typified the mood of brooding and concentrated inward thought preparatory to warlike action; in that of Giuliano, the type of alert and confident practical survey immediately preceding the moment of action. To this contrast of the meditative and active characters corresponds to some extent a contrast in the emblematic groups accompanying the portraits. At the feet of the Duke Giuliano recline the shapes of Night and Day,—the former a female, the latter a male personification,—the former sunk in an attitude of deep but uneasy slumber, the latter (whose head and face are merely blocked out of the marble) lifting himself in one of wrathful and disturbed awakening. But for Michelangelo's unfailing grandeur of style, and for the sense which his works convey of a compulsive heat and tempest of thought and feeling in the soul that thus conceived them, both these attitudes might be charged with extravagance. As grand, but far less violent, are those of the two companion figures that recline between sleep and waking on the sarcophagus of the pensive Lorenzo. Of these, the male figure is known as Evening, and the female as Morning (*Crepuscolo* and *Aurora*). In Michelangelo's original idea, figures of Earth and Heaven were to be associated with those of Night and Day on the monument of Giuliano, and others of a corresponding nature, no doubt, with those of the Morning and Evening Twilight on that of Lorenzo; these figures afterwards fell out of the scheme. Michelangelo's obvious and fundamental idea was, as some words of his own record, to exhibit the elements, and the powers of earth and heaven, lamenting the death of the princes; it is a question of much interest, but not to be discussed here, what other ideas of a more personal and deeper kind may have conflicted or come into association with these, and found expression in these majestic works of art, whereof no one who looks upon them can escape the spell.

Michelangelo had never ceased to be troubled by the heirs and executors of Julius, as well as by his own artistic conscience and ambition, concerning the long-postponed completion of the Julian monument. Agreement after agreement had been made, and then from the force of circumstances broken. In 1532, on the completion of the Medicean monuments at Florence, he entered into a new and what he firmly meant to be a binding contract to complete the work, on a scale once more very greatly reduced, and to set it up in the church of S. Pietro in Vincoli in Rome. But once more the demands of the pope diverted his purpose. Clement insisted that Michelangelo must complete his decorations of the Sixtine chapel by painting anew the great end wall above the altar, adorned until then by frescos of Perugino. The subject chosen was the Last Judgment, and Michelangelo began to prepare sketches. For the next two years he lived between Rome and Florence, and in the autumn of 1534, in his sixtieth year, settled finally and for the remainder of his life at Rome. Immediately afterwards Pope Clement died, and was succeeded by a Farnese under the title of Paul III. Even more than his predecessor, Paul insisted on claiming the main services of Michelangelo for himself, and forced him to let all other engagements drift. For the first seven years after the artist's return to Rome, his time was principally taken up with the painting of the colossal and multitudinous Last Judgment. This being completed in 1541, he was next compelled to undertake two more great frescos, one of the Conversion of Paul and another of the Martyrdom of Peter, in a new chapel which the pope had caused to be built in the Vatican, and named after himself *Capella Paolina*.

The fresco of the Last Judgment in the Sixtine chapel is probably the most famous single picture in the world. In it Michelangelo shows more than ever the omnipotence of his artistic science, and the fiery daring of his conceptions. The work exhibits the athletic unclothed human form in every variety and extremity of hitherto unattempted action and predicament. But of moderation, as well as of beauty and tenderness, it is almost entirely devoid. Whether from the complexion of his own thoughts, and the *sæva indignatio* that was native to his breast, or from the influence of the passionate and embittered theological temper of the time, Michelangelo has here neglected the consolatory aspects of Christianity, and insisted on its terrific aspects almost exclusively. Neither in the qualities of colour and execution is the work, so far as the condition of either admits comparison, comparable for charm to the earlier and far more nobly-inspired frescos of the ceiling. It is to these, and not to the Last Judgment, that the student must turn if he would realize what is best and greatest in the art of Michelangelo.

The frescos of the Pauline Chapel are on their part in part so injured as to be hardly susceptible of useful study or criticism. In their ruined state they bear evidence of the same tendencies that made the art of Michelangelo in its latest phase so dangerous an example to weaker men,—the tendency, that is, to seek for energy and violence of action both in place and out, for "terribleness" *quand même*, and to design actions not by help of direct study from nature, but by scientific deduction from the abstract laws of structure and movement. At best these frescos can never have been happy examples of Michelangelo's art.

During the fifteen years (1534–49) when Michelangelo was mainly engaged on these paintings, he had also at last been enabled to acquit himself, although in a manner that can have been satisfactory to none concerned, of his engagements to the heirs of Julius. Once more the influence of the pope had prevailed on them to accept a compromise altogether to their disadvantage. It was agreed that the Moses executed thirty years before should be the central figure of the new scheme; assistants were employed to carve two smaller flanking figures of female personifications; and the three were in 1545 set up in S. Pietro in Vincoli in combination with an architectural structure of rich but incongruous design. During the same years the long-pent human elements of fervour and tenderness in Michelangelo's nature had found vent and utterance such as they had never found before. He had occasionally practised poetry in youth, and there are signs of some transient love-passage during his life at Bologna. But it was not until towards his sixtieth year that the springs of feeling were fairly opened in the heart of this solitary, this masterful and stern, life-wearied and labour-hardened man. Towards that age we find him beginning to address impassioned sonnets, of which the sentiment is curiously comparable to that expressed in some of Shakespeare's, to a beautiful and gifted youth, Tommaso Cavalieri. Soon afterwards he made the acquaintance of the pious, accomplished, and high-souled lady, Vittoria Colonna, widow of the Marquis Pescara. For twelve years until her death, which happened in 1547, her friendship was the great solace of Michelangelo's life. On her, in all loyalty and reverence, he poured out all the treasures of his mind, and all his imprisoned powers of tenderness and devotion. He painted for her a crucifixion of extraordinary beauty, of which many imitations but not the original have come down to us. She was the chief inspirer of his poetry,—in which, along with her praises, the main themes are the Christian religion, the joys of Platonic love, and the power and mysteries of art. Michelangelo's poetical style is strenuous and concentrated like the man. He wrote with labour and much self-correction; we seem to feel him flinging himself on the material of language with the same overwhelming energy and vehemence,—the same impetuosity of temperament, combined with the same fierce desire of perfection,—with which contemporaries describe him as flinging himself on the material of marble.

And so the mighty sculptor, painter, and poet reached old age. An infirmity which settled on him in 1544, and the death of Vittoria Colonna in 1547, left him broken in health and heart. But his strength held on for many a year longer yet. His father and brothers were dead, and his family sentiment concentrated itself on a nephew, Leonardo, to whom he showed unremitting practical kindness, coupled with his usual suspiciousness and fitfulness of temper. In almost all his relations the old man continued to the end to manifest the same loyal and righteous heart, accompanied by the same masterful, moody, and estranging temper, as in youth. Among the artists of

the younger generation he held a position of absolute ascendency and authority; nor was his example, as we have said, by any means altogether salutary for them. During the last years of his life he made but few more essays in sculpture, and those not successful, but was much employed in the fourth art in which he excelled, that of architecture. A succession of popes demanded his services for the embellishment of Rome. For Paul III. he built the palace called after the name of the pope's family the Farnese. On the death of Antonio da San Gallo he succeeded to the onerous and coveted office of chief architect of St Peter's Church, for which he remodelled all the designs, living to see some of the main features, including the supports and lower portion of the great central dome, carried out in spite of all obstacles according to his plans. Other great architectural tasks on which he was engaged were the conversion of a portion of the Baths of Diocletian into the church of Sta Maria degli Angeli, and the embellishment and rearrangement of the great group of buildings on the Roman Capitol. At length, in the midst of these vast schemes and responsibilities, the heroic old man's last remains of strength gave way. He died on the threshold of his ninetieth year, on the 18th of February 1564.

For the bibliography of Michelangelo, which is extensive, see the useful though very imperfect compilation of Passerini, *Bibliografia di Michelangelo Buonarroti*, &c., Florence, 1875. The most important works, taken in chronological order, are the following:—P. Giovio, supplement to the fragmentary *Dialogus de viris litteris illustribus*, written soon after 1527, first published by Tiraboschi, *Storia della Letteratura italiana*, Modena, 1871; G. Vasari, in *Vite degli più eccellenti architettori, pittori, e scultori*, &c., Florence, 1550; A. Condivi, *Vita di Michelangelo Buonarroti*, 1553; this account, for which the author, a pupil and friend of the master's, had long been collecting materials, was much fuller than that of Vasari, who made use of it in rewriting his own life of Michelangelo for his second edition, which appeared after the master's death (1568). The best edition of Vasari is that by Milanesi, Florence, 1878–83; of Condivi, that by Gori and Mariette, Pisa, 1746. The first additions of importance were published by Bottari, *Raccolta di lettere sulla pittura*, &c., Rome, 1754 (2d ed., by Ticozzi, Milan, 1822); the next by Gaye, *Carteggio inedito*, 1840. Portions of the correspondence preserved in the Buonarroti archives were published by Guasti in his notes to the *Rime di Michelangelo Buonarroti*, 1863, and by Daelli in *Carte Michelangelesche inedite*, Milan, 1865. Complete biographies of Michelangelo had been meanwhile attempted by J. Harford, London, 1857, and with more power by Hermann Grimm, *Leben Michelangelo's*, Hanover (5th ed., 1879). A great increment of biographical material was at length obtained by the publication, in the four hundredth year after Michelangelo's birth, of the whole body of his letters preserved in the Buonarroti archives,—*Lettere di Michelangelo Buonarroti*, ed. G. Milanesi, Florence, 1875. This material was first employed in a connected narrative by A. Gotti, *Vita di Michelangelo*, Florence, 1875. Next followed C. Heath Wilson, *Life and Works of Michelangelo Buonarroti*, Florence, 1876, the technical remarks in which, especially as concerns the fresco-paintings, are valuable. Lastly, the combined lives of Michelangelo and Raphael by Professor A. Springer in Dohme's series of *Kunst u. Künstler*, Leipsic, 1878, contain the best biography of the master which has yet appeared. Of the poems of Michelangelo the best edition is that already referred to,—G. Guasti, *Rime di Michelangelo Buonarroti*, 1863; in earlier additions the text had been recklessly tampered with, and the rugged individuality of the master's style smoothed down. An edition with German translations was published by Hasenclever, Leipsic, 1875; for the English student the translations by Mr J. A. Symonds, in *Sonnets of Michelangelo and Campanella*, London, 1878, are invaluable. (S. C.)

MICHELET, Jules (1798–1874), one of the most voluminous and remarkable writers of France, and one who only lacked a keener power of self-criticism to make him one of the greatest, was born at Paris, August 21, 1798. He belonged to a family which had Huguenot traditions, and which was latterly occupied in the art of printing. His father was a master printer, but seems not to have been very prosperous, and the son at an early age assisted him in the actual work of the press. A place was offered him in the imperial printing office, but his father was able to send him to the famous Collége or Lycée Charlemagne, where he distinguished himself. He passed the university examination in 1821, and was shortly after appointed to a professorship or rather mastership of history in the Collége Rollin. Soon after this, in 1824, he married. The period of the Restoration and the July monarchy was one of the most favourable to rising men of letters of a somewhat scholastic cast that has ever been known in France, and Michelet had powerful patrons in Villemain, Cousin, and others. But, though he was an ardent politician (having from his childhood embraced republicanism and a peculiar variety of romantic free-thought), he was first of all a man of letters and an inquirer into the history of the past. His earliest works were school books, and they were not written at a very early age. Between 1825 and 1827 he produced divers sketches, chronological tables, &c., of modern history. His *Précis* of the subject, published in the last-mentioned year, is a sound and careful book, far better than anything that had appeared before it, and written in a sober yet interesting style. In the same year he was appointed maître de conférences at the École Normale. Four years later, in 1831, the *Introduction à l'Histoire Universelle* showed a very different style, exhibiting no doubt the idiosyncrasy and literary power of the writer to greater advantage, but also displaying the peculiar visionary qualities which make Michelet the most stimulating but the most untrustworthy (not in facts, which he never consciously falsifies, but in suggestion) of all historians. The events of 1830 had unmuzzled him, and had at the same time improved his prospects, and put him in a better position for study by obtaining for him a place in the Record Office, and a deputy-professorship under Guizot in the literary faculty of the university. Very soon afterwards he began his chief and monumental work, the *Histoire de France*, which occupied him for about forty years, and of which we shall speak presently. But he accompanied this with numerous other works, chiefly of erudition, such as the *Œuvres Choisies de Vico*, the *Mémoires de Luther écrits par lui-même*, the *Origines du Droit Français*, and somewhat later the *Procés des Templiers*. 1838 was a year of great importance in Michelet's life. He was in the fulness of his powers, his studies had fed his natural aversion to the principles of authority and ecclesiasticism, and at a moment when the revived activity of the Jesuits caused some real and more pretended alarm he was appointed to the chair of history at the Collége de France. Assisted by his friend Quinet, he began a violent polemic against the unpopular order and the principles which it represented, a polemic which made their lectures, and especially Michelet's, one of the most popular resorts of the day. He published, in 1839, a History of the Roman Republic, but this was in his graver and earlier manner. The results of his lectures appeared in the volumes *Le Prêtre, la Femme, et la Famille* and *Le Peuple*. These books do not display the apocalyptic style which, borrowed to a certain though no very great extent from Lamennais, characterizes Michelet's later works, but they contain in miniature almost the whole of his curious ethico-politico-theological creed—a mixture of sentimentalism, communism, and anti-sacerdotalism, supported by the most eccentric arguments, but urged with a great deal of eloquence. The principles of the outbreak of 1848 were in the air, and Michelet was not the least important of those who condensed and propagated them: indeed his original lectures were of so incendiary a kind that the course had to be interdicted. But when the actual revolution broke out Michelet, unlike many other men of letters, did not attempt to enter on active political life, and merely devoted himself more strenuously to his literary work. Besides continuing the great history, he undertook and

carried out, during the years between the downfall of Louis Philippe and the final establishment of Napoleon III., an enthusiastic *Histoire de la Révolution Française.* Despite or because of its enthusiasm, this is by no means Michelet's best book. The events were too near and too well known, and hardly admitted the picturesque sallies into the blue distance which make the charm and the danger of his larger work. In actual picturesqueness as well as in general veracity of picture, the book cannot approach Carlyle's; while as a mere chronicle of the events it is inferior to half a dozen prosaic histories older and younger than itself. The *coup d'état* lost Michelet his place in the Record Office, as, though not in any way identified with the republic administratively, he refused to take the oaths to the empire. But the new *régime* only kindled afresh his republican zeal, and his second marriage (with Mademoiselle Adèle Malairet, a lady of some literary capacity, and of republican belongings) seems to have further stimulated his powers. While the history steadily held its way, a crowd of extraordinary little books accompanied and diversified it. Sometimes they were expanded versions of its episodes, sometimes what may be called commentaries or companion volumes. In some of the best of them natural science, a new subject with Michelet, to which his wife is believed to have introduced him, supplies the text. The first of these (by no means the best) was *Les Femmes de la Révolution* (1854), in which Michelet's natural and inimitable faculty of dithyrambic too often gives way to tedious and not very conclusive argument and preaching. In the next, *L'Oiseau* (1856), a new and most successful vein was struck. The subject of natural history was treated, not from the point of view of mere science, nor from that of sentiment, nor of anecdote, nor of gossip, but from that of the author's fervent democratic pantheism, and the result, though, as was to be expected, unequal, was often excellent. *L'Insecte*, in the same key, but duller, followed. It was succeeded by *L'Amour* (1859), one of the author's most popular books, and not unworthy of its popularity, but perhaps hardly his best. These remarkable works, half pamphlets half moral treatises, succeeded each other as a rule at the twelve months' interval, and the succession was almost unbroken for five or six years. *L'Amour* was followed by *La Femme* (1860), a book on which a whole critique of French literature and French character might be founded. Then came *La Mer* (1861), a return to the natural history class, which, considering the powers of the writer and the attraction of the subject, is perhaps a little disappointing. The next year (1862) the most striking of all Michelet's minor works, *La Sorcière*, made its appearance. Developed out of an episode of the history, it has all its author's peculiarities in the strongest degree. It is a nightmare and nothing more, but a nightmare of the most extraordinary verisimilitude and poetical power.

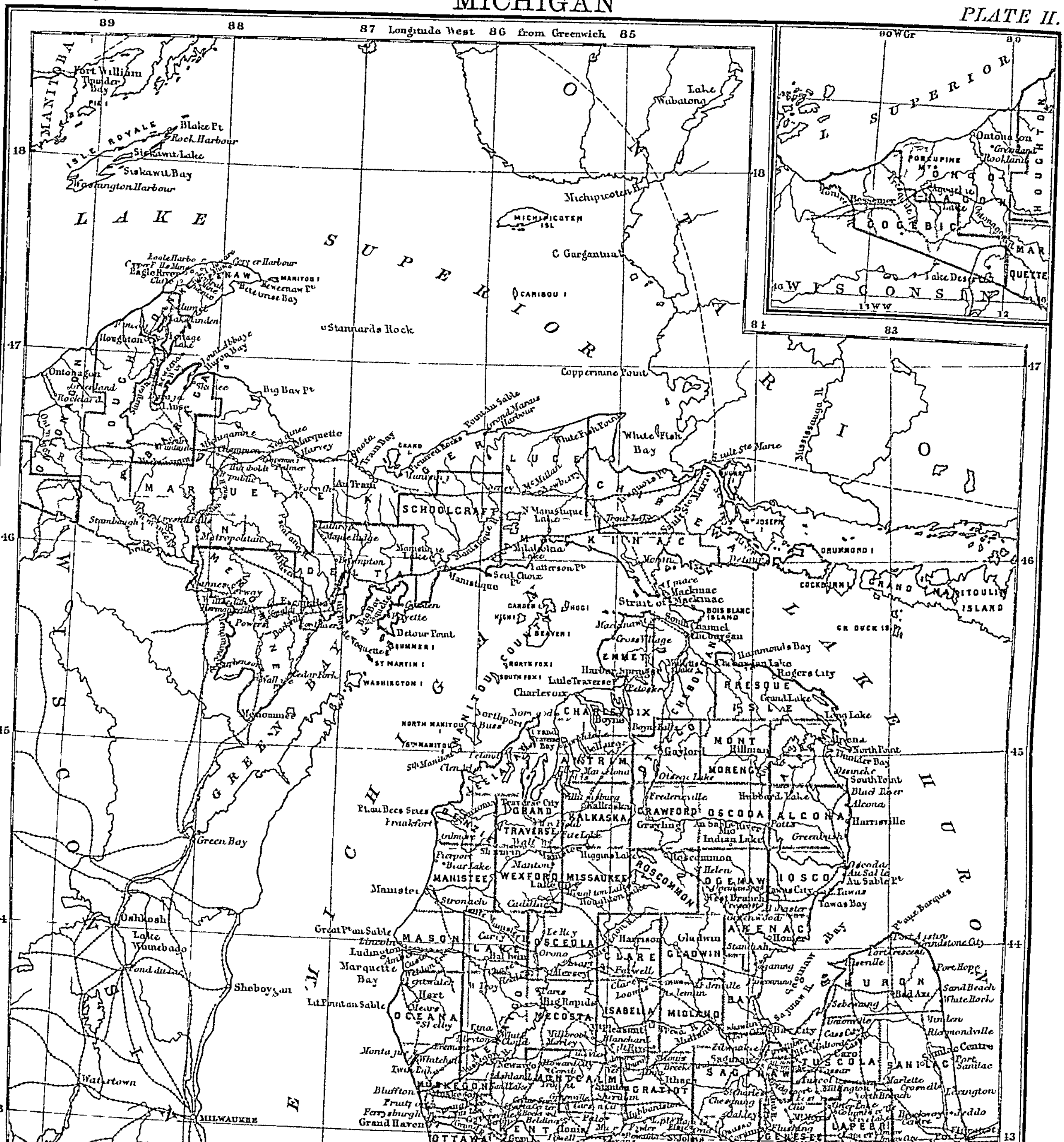
This remarkable series, every volume of which was at once a work of imagination and of research, was not even yet finished, but the later volumes exhibit a certain falling off. The ambitious *Bible de l'Humanité* (1864), an historical sketch of religions, has but little merit. In *La Montagne* (1868), the last of the natural history series, the tricks of staccato style are pushed even farther than by Victor Hugo in his less inspired moments, though—as is inevitable in the hands of such a master of language as Michelet—the effect is frequently grandiose if not grand. *Nos Fils* (1869), the last of the string of smaller books published during the author's life, is a tractate on education, written with ample knowledge of the facts and with all Michelet's usual sweep and range of view, but with visibly declining powers of expression. But in a book published posthumously, *Le Banquet*, these powers reappear at their fullest. The picture of the industrious and famishing populations of the Riviera is (whether true to fact or not) one of the best things that Michelet has done. To complete the list of his miscellaneous works, two collections of pieces, written and partly published at different times, may be mentioned. These are *Les Soldats de la Révolution* and *Légendes Démocratiques du Nord.*

The publication of this series of books, and the completion of his history, occupied Michelet during both decades of the empire. He lived partly in France, partly in Italy, and was accustomed to spend the winter on the Riviera, chiefly at Hyères. At last, in 1867, the great work of his life was finished. As it is now published it fills nineteen volumes. The first of these deals with the early history up to the death of Charlemagne, the second with the flourishing time of feudal France, the third with the 13th century, the fourth, fifth, and sixth with the Hundred Years' War, the seventh and eighth with the establishment of the royal power under Charles VII. and Louis XI. The 16th and 17th centuries have four volumes apiece, much of which is very distantly connected with French history proper, especially in the two volumes entitled *Renaissance* and *Réforme.* The last three volumes carry on the history of the 18th century to the outbreak of the Revolution. The characteristics which this remarkable history shares with Michelet's other works will be noted presently. At present it may be remarked that, as the mere division of subjects and space would imply, it is planned on very original principles. Michelet was perhaps the first historian to devote himself to anything like a picturesque history of the Middle Ages, and his account is still the most vivid though far from the most trustworthy that exists. His inquiry into manuscript and printed authorities was most laborious, but his lively imagination, and his strong religious and political prejudices, made him regard all things from a singularly personal point of view. Circumstances which strike his fancy, or furnish convenient texts for his polemic, are handled at inordinate length, while others are rapidly dismissed or passed over altogether. Yet the book is undoubtedly the only history of France which bears the imprint of genius, and in this respect it is not soon likely to meet a rival.

Uncompromisingly hostile as Michelet was to the empire, its downfall and the accompanying disasters of the country once more stimulated him to activity. Not only did he write letters and pamphlets during the struggle, but when it was over he set himself to complete the vast task which his two great histories had almost covered by a *History of the Nineteenth Century.* He did not, however, live to carry it further than Waterloo, and the best criticism of it is perhaps contained in the opening words of the introduction to the last volume—"l'âge me presse." The new republic was not altogether a restoration for Michelet, and his professorship at the Collége de France, of which he contended that he had never been properly deprived, was not given back to him. He died at Hyères on the 9th of February 1874, and an unseemly legal strife between his representatives took place as to his funeral.

The literary characteristics of Michelet are among the most clearly marked and also among the most peculiar in French literature. A certain resemblance to Lamennais has been already noted, and to this may be added an occasional reminiscence of the manner of Bossuet. But in the main Michelet, even in the minor details of style, is quite original and individual. His sentences and paragraphs are as different as possible in construction and rhythm from the orderly architecture of French classical prose. A very frequent device of his (somewhat abused latterly) is the omission of the verb, which gives the sentence the air of a continued interjection. Elsewhere he breaks his phrase, not finishing the regular clause at all. In these points and many others the resemblance to his contemporary Carlyle is very striking; and, different as were their points of view, their manners of seeing were by no means unlike. History to Michelet is always picturesque; it is a series of tableaux. Allusion has been already made to the singular per-

MICHIGAN



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spective in which these tableaux are drawn, a perspective so strange that a reader unacquainted with the actual size and relation of the objects represented is certain to be deceived. Nothing indeed is further from Michelet's purpose than deceit. Although a strong republican, an ardent anti-sacerdotalist, and a patriot of fanatical enthusiasm, he is always scrupulously fair as far as he understands what he is doing. For instance, his hatred for England and Englishmen is one of the most comically intense passions in literature. He is never tired of exclaiming against their diabolical pride, their odious jealousy of France, their calculating covetousness, and so forth. In his excited imagination the long drama of European history is a kind of conflict of Ormuzd and Ahriman, in which France, it is needless to say, plays the first part and England the second. Yet he is never unfair to English fortitude and coolness, never (after the childish fashion of some of his countrymen) slurs over English victories, and often expresses genuine admiration (mixed, it is true, with a shudder or two of aversion) for the masterful ways and constantly advancing prosperity of the English people. So, with all his dislike to the priesthood, he never is chary of praise to pope or monk whenever it can fairly be given, and, with all his republicanism, he is never weary of worshipping the heroism of a great king. But his poetical fashion of dealing with events, his exaggeration of trivial incidents into great facts of history, his fixed ideas, especially in reference to the intellectual and social condition of mediæval times, the evils of which he enormously exaggerates, and his abiding prejudices of a general kind combine to distort his accounts in the strangest fashion. A laborious person might pick out of contemporary authors a notable collection of erroneous views of which Michelet is not so much the author as the suggester, for it is when his brilliant exaggerations are torn from their context and set down in some quite other context as sober gospel that they are most misleading to those who do not know the facts, and most grotesque to those who do. This is especially the case in regard to literature. Michelet began his great work too early to enjoy the benefit of the resurrection of old French literature which has since taken place; and though his view of that literature partakes of the amorous enthusiasm which colours his view of everything French, it is astoundingly incorrect in detail. The most remarkable passage of all perhaps is the passage in his *Renaissance* relating to Rabelais, Ronsard, and Du Bellay, a passage so widely inconsistent not only with sound criticism but with historic fact that the author (a very rare thing with him) makes a kind of half apology for it elsewhere. Of the work of the age of chivalry proper, the chansons de gestes, the Arthurian romances, the early lyrics and dramas, he evidently knew but little, and chose to subordinate what he did know to his general theories of the time. Even much later his praise and blame, though transparently honest, are quite haphazard. Unless, therefore, the reader be gifted with a very rare faculty of applying the "grain of salt" to what he reads, or unless he be well acquainted with the actual facts before coming to Michelet's version of them, he will almost certainly be misled. But despite this grave drawback (which attends all picturesque history) the value of Michelet merely as an historian is immense. Not only are his separate tableaux, the wonderful geographical sketch of France in the beginning of the book, the sections devoted to the Templars, to Joan of Arc, to the Renaissance, to the Camisards, almost unequalled, but the inspiriting and stimulating effect of his work is not to be surpassed. If his reconstruction is often hazardous and conjectural, sometimes definitely and demonstrably mistaken, and nearly always difficult to adjust entirely to the ascertained facts, it is always possible in itself, always instinct with genius, and always life-like. There are no dead bones in Michelet; they are if anything only too stirring and lively. These criticisms apply equally to the minor books, though these are necessarily fuller of the author's somewhat wearisome propaganda, and less full of brilliantly painted facts. The great fault of Michelet as of not a few other modern authors is the comparatively improvised and ephemeral character of too much of his work. His immense volume is, much of it, mere brilliant pamphleteering, much more mere description equally brilliant but equally liable to pass. Nevertheless he is (especially in French, the language *par excellence* of measured and academic perfection) so characteristic and singular a figure in his turbid eloquence and fitful flashing insight that he is never likely to lose a place, and a notable one, in literary history.

Almost all Michelet's works, the exceptions being his translations, compilations, &c., are published in uniform size and in about fifty volumes, partly by Marpon and Flammarion, partly by Calmann Lévy. (G. SA.)

MICHELL, John, an eminent English man of science of the 18th century. He received his university education at Queen's College, Cambridge. His name appears fourth in the Tripos list for 1748–49; and in 1755 he was moderator in that examination. He was a fellow of his college, and became successively Woodwardian professor of geology (in 1762) and rector of Thornhill in Yorkshire. He was elected a member of the Royal Society in the same year as Henry Cavendish (1760). He died in 1793. In 1750 he published at Cambridge a small work of some eighty pages, entitled *A Treatise of Artificial Magnets, in which is shown an easy and expeditious method of making them superior to the best natural ones.* Besides the description of the method of magnetization which still bears his name, this work contains a variety of acute and accurate magnetic observations, and is particularly distinguished by a lucid exposition of the nature of magnetic induction. He is now best known as the original inventor of the torsion balance, which afterwards became so famous in the hands of its second inventor Coulomb. Michell described it in his proposal of a method for obtaining the mean density of the earth. He did not live to put his method into practice; but this was done by Henry Cavendish, who made, by means of Michell's apparatus, the celebrated determination that now goes by the name of Cavendish's experiment (*Phil. Trans.*, 1798).

Michell's other contributions to science are—"Conjectures concerning the Cause and Observations upon the Phenomena of Earthquakes," *Phil. Trans.*, 1760; "Observations on the Comet of January 1760 at Cambridge," *Ib.*, 1760; "A Recommendation of Hadley's Quadrant for Surveying," *Ib.*, 1765; "Proposal of a Method for measuring Degrees of Longitude upon Parallels of the Equator," *Ib.*, 1766; "An Inquiry into the Probable Parallax and Magnitude of the Fixed Stars," *Ib.*, 1767; "On the Twinkling of the Fixed Stars," *Ib.*, 1767; "On the Means of Discovering the Distance, Magnitude, &c., of the Fixed Stars," *Ib.*, 1784.

MICHELOZZI, Michelozzo (1391–1472?), was a Florentine by birth, the son of a tailor, and in early life a pupil of Donatello. He was a sculptor of some ability in marble, bronze, and silver. The statue of the young St John over the door of the Duomo at Florence, opposite the Baptistery, is by him; and he also made the beautiful silver statuette of the Baptist on the altar-frontal of San Giovanni. Michelozzi's great friend and patron was Cosimo I. dei Medici, whom he accompanied to Venice in 1433 during his short exile. While at Venice, Michelozzi built the library of San Giorgio Maggiore, and designed other buildings there. The magnificent Palazzo dei Medici at Florence, built by Cosimo, was designed by him; it is one of the noblest specimens of Italian 15th-century architecture, in which the great taste and skill of the architect has combined the delicate lightness of the earlier Italian Gothic with the massive stateliness of the Classical style. With great engineering skill Michelozzi shored up, and partly rebuilt, the Palazzo Vecchio, then in a ruinous condition, and added to it many important rooms and staircases. When, in 1437, through Cosimo's liberality, the monastery of San Marco at Florence was handed over to the Dominicans of Fiesole, Michelozzi was employed to rebuild the domestic part and remodel the church. For Cosimo I. he designed numerous other buildings, mostly of great beauty and importance. Among these were a guest-house at Jerusalem, for the use of Florentine pilgrims, Cosimo's summer villa at Careggi, and the strongly fortified palace of Cafagiuolo in Mugello. For Giovanni dei Medici, Cosimo's son, he built a very large and magnificent palace at Fiesole. In spite of Vasari's statement that he died at the age of sixty-eight, he appears to have lived till 1472. He is buried in the monastery of San Marco, Florence. Though skilled both as a sculptor and engineer, his fame chiefly rests on his architectural works, which claim for him a position of very high honour even among the greatest names of the great 15th-century Florentines.

MICHIGAN, one of the States of the American Union, Plate II.
situated in the region of the great lakes. It lies between 41° 42′ and 47° 32′ N. lat., and 82° 24′ and 90° 31′ W. long., the centre of the State being 670 miles north of west from New York, the nearest point on the seaboard. The area is 58,915 square miles. The State consists of two

natural divisions, known as the Upper and the Lower Peninsula. The Upper or Northern Peninsula is bounded on the N., E., and S. by Lakes Superior, Huron, and Michigan, and on the W. by the river St Mary and the State of Wisconsin. The Lower Peninsula is bounded on the W., N., and E. by Lakes Michigan, Huron, St Clair, and Erie, and the St Clair and Detroit rivers, and on the S. by the States of Ohio and Indiana. The general contour of the Lower Peninsula approaches that of a horse-shoe, with an average width of about 200 miles from east to west and a length of about 300 miles from north to south. Its surface gradually rises in gentle undulations from the surrounding lakes to an elevation of about 400 feet above Lake Huron, no point reaching an altitude of more than 600 feet. The Upper Peninsula is much more rugged in contour and surface, at some points reaching an elevation of about 1100 feet. The territory was originally covered with forests, with only here and there a small open prairie. It abounds in fine inland lakes, with areas varying from a few acres to several miles. The rivers are not large enough to be navigable, but they afford ample water-power, and are particularly valuable for floating down the logs of the lumbering districts. The coast-line of the State is not less than about 1600 miles in length; and along the whole of this distance vessels of 2000 tons may pass without losing sight of land.

Geological Formation.—The Lower Peninsula occupies the central part of a great basin, the borders of which extend to the east as far as London, Ontario, and to the west as far as Madison, Wisconsin. Within these limits the traveller starting in any direction from the centre of the State encounters successively the outcropping edges of older and older strata. The whole series has been likened to a nest of wooden dishes; it embraces not only the Laurentian and Huronian systems but also the numerous groups that go to make up the Silurian, the Devonian, the Carboniferous, and the Quaternary systems. These several formations are covered almost universally with a drift of finely comminuted and triturated rock, borne thither by moving glaciers and floating icebergs, or washed to its present position by currents of water, while the surface was still submerged. This loose material varies in thickness, sometimes extending to a depth of 200 or 300 feet. While the lower formations contain almost inexhaustible deposits of copper, iron, gypsum, and salt, the surface soil is pre-eminently fertile, uniting all the mineral constituents necessary for the most luxuriant growth of plants. There are limited areas of light and somewhat sterile drift soil; but even these have shown themselves under proper treatment to be capable of yielding a rich vegetation. For the most part the drift soil is composed of a mixture of clay with sand and gravel. It is easily cultivated, is retentive of moisture, and is sufficiently porous to prevent the injury of crops by excessive rains.

Climate and Natural Products.—The mean temperature of Lansing, the capital of the State, as determined by observations extending through eighteen years, is 46°·71 Fahr., or about the same as that of Berlin. During the summer months the mean temperature is nearly the same as that of Vienna; in the winter it is nearly that of Stockholm. The annual rainfall during the eighteen years previous to 1882 was about 31 inches. This is very evenly distributed throughout the year, though a little more than half the amount falls in the five months from May to October. The average snowfall in the centre of the State is about 4 feet, though it is seldom that more than 12 inches lie on the ground at any one time. The winter temperature is much modified by the open water of the adjacent lakes. The severe winds are commonly from the west and north-west; but in sweeping across the open waters of Lake Michigan they are so far softened as to make the climate much milder than that found in the same latitude on the western side of the lake. This peculiarity is specially favourable to the growth of fruits. Peaches are grown successfully along the 45th parallel, and figs thrive in the open air in lat. 42½°. The modifying influence of the lake winds also gives great variety to the flora. The predominant woods are oak, maple, beech, elm, ash, cherry, hickory, walnut, basswood, and pine. All these grow luxuriantly in the vast forests of the State, and afford an abundant supply of the best timber. There are 165 species of trees and shrubs indigenous to Michigan; and the entire flora of the State makes a list of 1634 species.

Cereals and Fruits.—The most important crop of Michigan is wheat, and the average yield per acre, as shown by the latest census, is greater than that of any other State in the Union. The acres sown in 1879 were reported as 1,822,749, and the amount produced as 35,532,543 bushels. These figures show that Michigan is fourth in rank of the wheat-producing States, the number of bushels grown being exceeded by the crops of Illinois, Ohio, and Indiana. In 1879 the yield in bushels of the other principal cereals is shown by the following figures:—Indian corn, 32,461,452; oats, 18,190,793; barley, 1,204,316; rye, 294,918; buckwheat, 413,062; clover seed, 313,063; pease, 538,332. The crop of potatoes in the same year was 8,025,475 bushels, and the hay amounted to 1,051,115 tons. Of the fruits grown in the State apples are the most important, and these are believed to be unsurpassed in excellence in any country in the world. The sales in 1880 were 4,834,936 bushels, a considerable quantity going to the markets of Europe. Next in importance is the peach crop, annually gathered from more than fifty of the counties of the State. In 1880 the peach orchards were reported as covering 12,908 acres, and the fruit sold as amounting to 413,418 bushels. The long coast-line of Lake Michigan affords easy access to market even for the most perishable fruits. Besides the facilities thus afforded, the railroads that now thread the State, with an aggregate length in March 1882 of 4332 miles, afford abundant means of rapid transportation. As the fruit belt extends from north to south more than 200 miles, the danger of disastrous competition in the markets is obviated by prolongation of the season of ripening. At the meeting of the State Horticultural Society held in 1881 it was reported that the average value of the peach crop per acre was above $125. The ten volumes of the *Transactions* of the State Horticultural Society published since its organization in 1870 show that the development of fruit culture within the last decade has been much more rapid than in any other State.

Lumber.—The timber produce in Michigan is of superior quality, and the amount is so great that about two-thirds of the best lumber sold in New York, Philadelphia, and Boston go out from its mills. The logs are borne along the lakes, rivers, and small watercourses to the booms of mills situated at convenient points, where the timber is sawed and shipped for the different markets of the world. Of these manufacturing districts those known as the Saginaw, the Grand River, and the Muskegon valleys are the most important. The Saginaw receives the waters of the Tittabawasse, the Cass, the Flint, the Shiawassee, the Bad, the Pine, the Chippewa, the Tobacco, and their numerous tributaries, draining a vast region that still yields an undiminished supply of pine. The forests of the western parts of the State are easily accessible by the Grand River and its tributaries, while those still farther north find a natural outlet through the numerous streams that flow to Lake Michigan. On the banks of these watercourses are

some of the largest and finest mills of the world. In 1854, when the first effort was made to collect statistics of this industry, it was found that there were only sixty-one mills in operation, and that the entire annual product was only 108,000,000 feet. Eighteen years later, in 1872, it was estimated that the annual product was not less than 2,560,000 feet of oak, 12,700,000 of staves, 300,000,000 lath, 400,000,000 shingles, and 2,500,000,000 of sawed pine. The number of saw-mills had already reached about 1500, the number of persons employed 20,000, and the capital represented $25,000,000. In 1881 the manufacture of pine lumber amounted to 3,919,500,000 feet, the value of which exceeded $60,000,000. The aggregate value of the forest products of the State was estimated in 1881 to have reached more than $1,000,000,000. *Forestry Bulletin*, No. 6, issued December 1, 1881, estimated the amount of standing white pine of merchantable quality at 35,000,000,000 feet, and the amount of standing hard wood at 700,000,000 cords. Besides these amounts, the same authority estimates the amount of hemlock at 7,000,000,000 feet, with 7,000,000 cords of bark, and an aggregate of 70,000,000 of cedar and tamarack. It is probable that before many years the hard wood produced by the State will approach in value the figures representing the value of the pine now sent to the markets of the world. It is probable that Michigan for many years to come will maintain its precedence as a lumber-producing State.

Mineral Resources.—Of the mineral products of Michigan the most important is iron. As early as 1842 the report of the first State geologist, Dr Douglas Houghton, called attention to the presence of hæmatite ore, though for a considerable time after this it was not found in such quantities as to make it certain that mining could be made profitable. Before 1860, however, it became known that iron in the Upper Peninsula not only existed in vast quantities, but also that it was of superior quality. From that time iron-mines were rapidly developed, until in 1881 they had come to exceed in value, though not in amount, even the products of Pennsylvania. In 1880 the product was 1,834,712 tons, with a value at the mines of $6,034,648, as against the yield in Pennsylvania of 2,185,675 tons, with a value of $5,517,079. The product of Michigan in 1882 was 2,948,307 tons of ore, with a market value of about $25,000,000. The Michigan minerals are of extraordinary richness,—62·9 per cent. being the average of the first-class ores, while the furnace books often show a much higher yield.

Next in importance to the iron-mines are those of copper. These are also situated in the Northern Peninsula, in the mountain range of trappean rocks which crown the point of land extending northwards into Lake Superior. This secondary peninsula or cape, known as Keweenaw Point, rises to an average height of about 600 feet above the lake, the highest pinnacles reaching nearly double that altitude. This point contains what are believed to be the richest copper-mines ever discovered; the metal is not found as an ore, but as virgin copper almost chemically pure. It has only to be separated from its rocky matrix, when it is ready for the market. The largest of the copper-mines, that at Calumet, has built up an industry which employs 2000 men, and its total product of refined copper in 1882 was no less than 50,770,719 ℔, or one-eighth of the annual production of copper in the world. In quality the copper of the Lake Superior district is such that it commands the highest price at home and abroad. Its tenacity is remarkable, and therefore it is eagerly sought after for cartridges by all the great military powers. In 1882 the copper-mines paid dividends amounting to $2,900,000,—making an aggregate of $28,248,000 since they were opened.

Within a few years the salt-works of Michigan have also come to exceed those of any other State in the Union. The first well was sunk in 1859–60, but in 1882 the production was found to have exceeded that of the famous works in New York, and to have amounted in that year to no less than 3,204,921 barrels. The extraordinary development of this industry is due to several causes. A careful system of inspection by State authority has kept its salt unsurpassed in purity. The salt basin is not only accessible by navigable waters, so as to have the advantage of cheap transportation, but the wells are situated in the great lumber-producing districts, and the manufacture is thus carried on at very small expense, in connexion with the saw-mills. The power is furnished by the same engines, the exhausted steam is used for the evaporation of brine during the day, and during the night evaporation is still carried on by means of refuse wood and saw-dust, while the staves for barrels are made from rejected timber. By this system the best quality of salt is obtained at a minimum expense. The chief reservoir of salt is the series of sandstones and shales constituting the Waverly group. This salt-producing rock covers no less than about 8000 square miles, and it is safe to presume that the supply is inexhaustible. The average depth of the wells is about 800 feet, but in some localities wells sunk to nearly 2000 feet have been remunerative. Important salt-works have recently been developed in the western part of the State.

There are also certain other minerals of considerable importance. Deposits of gypsum, easily accessible, practically inexhaustible in quantity, and superior in quality, are found in several localities both in the eastern and in the western parts of the Lower Peninsula. In the outskirts of Grand Rapids the deposit crops out at the surface, and at an average depth of from 40 to 70 feet extends over an area of 10 or 12 square miles. The rock is easily quarried, and is either ground for use as a fertilizer or calcined into plaster of Paris. The deposits of coal are supposed to cover about 8000 square miles, but as yet the product at any one point has not been very considerable. In quality the coal is highly bituminous, and is not sufficiently pure to be useful for smelting or for the manufacture of gas. For these reasons the stock of coal in the State is practically untouched. If future explorations and experiments should make these deposits available, a new era in the manufacture of iron will be the result. At present the coal for smelting the Lake Superior ores is brought chiefly from Ohio and Pennsylvania. Quarries of limestone and of sandstone have been opened in various parts of the State. The brown stone of the Upper Peninsula is of excellent quality, and is capable of receiving a high finish. The supply is inexhaustible, and the accessibility of the quarries by water gives promise of a thriving industry. The grindstones taken from the Huron county quarries are of superior quality, and the slates found in unlimited quantities on the shores of the Huron Bay are unsurpassed in point of durability and colour. Clays and sands of commercial value are found in great abundance. Though the manufacture of glass is yet in its infancy, sands in large quantities have been discovered in Monroe county suitable for the manufacture of plate glass of excellent quality. Brick and tile clays are found in all parts of the State. Though native silver has been found in small quantities in the Upper Peninsula, the systematic mining of this metal has not yet been carried on with successful results. The *Report* of the commissioner of mineral statistics for 1882 shows that, except as to coal, Michigan is the foremost of all the States in mineral wealth.

Fisheries.—The geographical position of Michigan explains the fact that its fresh-water fisheries are the most productive in the United States. The most important varieties of fish are lake-trout,

sturgeon, bass, pickerel, herring, brook-trout, grayling, and white-fish. General laws for the protection of fish have been passed; and a fish commission has been maintained for some years for the purpose of propagating the best varieties and planting them in waters adapted to their natural development. Up to the close of 1880 the commissioners had planted about 80,000,000 young white-fish, 1,000,000 silver eels, 1,000,000 lake-trout, 2,000,000 salmon, and 500,000 brook-trout, besides smaller numbers of shad, grayling, pike, and bass. Excellent results have followed, especially in the multiplication of white-fish, salmon, and eels. In 1879 the total "take" was 24,013,100 lb, of which 12,902,250 lb were white-fish, the most valuable lake-fish known to epicures and to commerce. During winter large quantities preserved by freezing are taken to Eastern markets, where they are readily sold at a high price.

Educational Institutions.—As early as 1785 the law of congress which provided for the sale of lands north of the Ohio river reserved for the support of public schools "section 16" of each township. This fundamental law devoted to educational purposes one-thirty-sixth of all the lands of that vast domain known as the north-western territory. The "ordinance of 1787," by which this territory was organized, further provided that "schools and the means of education shall for ever be encouraged." In 1826 this congressional action was supplemented by a grant to Michigan of two townships of land for the founding and support of a university. When Michigan became a State in 1837, its educational policy took definite form. The constitution provided, not only that the grant of "section 16" should be devoted exclusively to the support of schools of the primary grade, but also that the State and not each township should be the custodian of the lands so appropriated. The constitution expressly provided that the proceeds from the sale of "school lands" should be held by the State as a perpetual fund, the interest of which should be annually applied to the support of primary schools. The lands devoted to school purposes in Michigan under these provisions amounted to 1,077,209 acres, of which, in September 1881, 675,000 acres had been sold. On the sum realized by these sales, $3,095,679, the State pays interest at 7 per cent., and the resulting income, amounting to $216,645, is annually distributed to the schools. This source is supplemented from local taxes, so that in 1881 the total sum realized from all sources for the primary schools was $3,644,778.

The schools organized under State law are known as graded and ungraded. In the small districts where the schools are under the charge of but one or two teachers, grading is impracticable. Of ungraded districts there were in 1881 6120, attended by 219,570 children, while the graded schools were 404 in number, with an attendance of 152,043. The school census includes all children between the ages of five and twenty, amounting in 1881 to 518,317, of whom there was an average attendance of 391,401. To all children of school age the public schools are free, though a fee may be required for advanced studies in the high schools. The immediate administration of the schools is entrusted to school officers elected annually by the tax-payers of the individual districts. The State constitution requires that a free school shall be in session at least three months of every year in each district. In districts of more than 30 and less than 800 children, the law requires at least five months of school; while in districts of more than 800 children, the session must be not less than nine months in length. In the graded schools the division is into primary schools, grammar schools, and high schools, each of these divisions retaining the scholar ordinarily four years. At the end of the course the student is ready for the university, to which, under certain restrictions provided by the university itself, he is admitted on diploma from the high school. The university of Michigan, situated at Ann Arbor, was first opened for instruction in 1841. It now (1883) consists of the department of literature, science, and the arts, the department of medicine, the department of law, the college of homœopathic medicine, the school of pharmacy, the college of dental surgery, and the school of political science. Connected with the medical departments are the State hospitals. In 1881–82 there were 86 officers of instruction and 1534 students. The total income for the year 1879–80 from Federal grant, State grants, and fees was $231,339. The general control of the university is placed in the hands of eight regents elected by popular suffrage at the biennial spring elections, two regents being chosen at each election. The normal school, situated at Ypsilanti, and generously supported by the State, may be said to complete the school system.

Charitable and Reformatory Institutions.—A school for the deaf, dumb, and blind, instituted under an Act passed in 1848, is situated at Flint, about 60 miles north-west of Detroit; in February 1882 it had 249 pupils. In 1879 a distinct school for the training of the blind was established at Lansing. The "State public school for dependent and neglected children" is devoted to the systematic education of such children as otherwise would have to be maintained in the county poorhouses. The pupils are divided into "families" of about thirty each, and are cared for in separate cottages, each cottage being under the charge of a "cottage manager." The school receives dependent children of sound health, and free from contagious disease; and it is made the duty of the officers having charge of the poor to send all such children between the ages of three and twelve to it. This institution, the pioneer of its kind, and one of the most useful of charitable schools, is situated at Coldwater, 132 miles south-west of Detroit. In February 1882 there were 320 children and 21 officers and teachers. The "Reform School" at Lansing is designed to reclaim juvenile offenders who have been convicted of some offence. A farm of 224 acres connected with the school is, in considerable part, tilled by the boys. The number of inmates in February of 1882 was 325. A similar school at Adrian has recently been instituted for girls. There are State asylums for the insane at Kalamazoo (715 patients) and Pontiac (499 patients). The legislature of 1881 provided for the establishment of an additional asylum in one of the northern counties of the Lower Peninsula.

Population.—In 1837 the State had 174,647 inhabitants. The numbers according to the different census returns from 1840 are given in the following table:—

Census.	Total	Males.	Females.	Density per Square Mile.
1840	212,267	113,788	98,479	3·77
1850	397,654	209,897	187,757	7·07
1860	749,113	394,694	354,419	12·11
1870	1,184,059	617,745	566,314	20·01
1880	1,636,937	862,678	774,259	27·80

At the last census 388,508 of the inhabitants were of foreign birth, 97,346 being natives of the United Kingdom, 89,085 Germans, and 16,445 Scandinavians. In point of population the State, which was twenty-third in 1840, now stands ninth in the Union.

The following are the principal cities in the State, with population at the census of 1880:—Detroit, 116,340; Grand Rapids City, 32,016; Bay City, 20,693; East Saginaw City, 19,016; Jackson City, 16,105; Muskegon City, 11,262; Saginaw City, 10,525; Port Huron, 8883; Flint City, 8410; Lansing (the State capital), 8319; Ann Arbor, 8061; Adrian City, 7849; Battle Creek, 7063; Manistee, 6930; West Bay City, 6397; Alpena City, 6153; Ishpeming, 6039.

History and Government.—The State of Michigan is part of the territory that was first settled by the French, and until the fall of Canada into the hands of the British after the middle of the 18th century was under the government of New France. The territory was explored by Jesuit missionaries in the 17th century; but, although it was known at an early period that the lands were of exceptional excellence, very little progress was made in developing the resources of the territory until after the completion of the first half-century of the American Union. The surveyors employed by the general government to inspect the lands and report as to their fitness for settlement by the soldiers of the war of 1812 appear to have derived their impressions almost exclusively from the low lands in the south-eastern corner of the territory. The report, accordingly, was not favourable; and consequently the tide of immigration that had already begun to set in flowed steadily past Michigan into the territories farther west. It was largely for this reason that the early development of Indiana, Illinois, Iowa, and Wisconsin was somewhat more rapid than that of Michigan. But gradually the false impressions concerning the soil and climate were dispelled; and within the past few years the increase of the population and the growth of wealth have been very rapid. In 1851 the valuation of the State for purposes of taxation (which excludes much valuable property) was $30,976,270; in 1861, $172,055,808; in 1871, $630,000,000; at 1881, $810,000,000. The State constitution, adopted in 1837 at the time of admission to the Union, has been modified in some minor particulars; but in most respects it remains unchanged. The governor is elected for two years, with no restriction as to re-election. The legislature meets biennially in the first week of January, and usually continues in session till May. The supreme court consists of four judges chosen by popular vote for terms of eight years, one being elected every second year. Judges have been so frequently re-elected that the office may be said to be practically a permanent one, with a provision for termination in case of need. The State is divided into twenty-two judicial districts, in each of which a circuit court sits for the trial of causes of original jurisdiction, and of causes appealed from the justice courts. The judges of the circuit courts are also elected by popular suffrage. On political questions voting is open to all naturalized citizens of the male sex more than twenty-one years of age unless prevented by some natural disqualification. At school meetings the right of suffrage is extended so as to include tax-payers of either sex.

Authorities.—Frederick Morley, *Michigan and its Resources*, compiled under authority of the State, 2d ed., Detroit, 1882; *Walling's Atlas of Michigan, with an Account of the Topography, Climate, and Geology of the State*, by Alex. Winchell, LL.D.; James V. Campbell, *Outlines of the Political History of Michigan*; *Reports of the Secretary of the State Pomological Society of Michigan from* 1871 *to* 1880; *Report of the Commissioner of Education for* 1880: *Forty-fifth*

Annual Report of the Superintendent of Public Instruction of the State of Michigan for the year 1881; *Reports of the Geological Survey of the State of Michigan*, 1869-80, 4 vols.; *Special Report of Commissioner of Mineral Statistics*, March 1883; *Forestry Bulletins* for 1881. (C. K. A.)

MICHIGAN, LAKE. See ST LAWRENCE.

MICHIGAN CITY, a town of the United States, in Laporte county, Indiana, on the south-east shore of Lake Michigan, 40 miles east-south-east of Chicago. As a lake-port and a junction for several railroads, it is a place of considerable prosperity. It is the largest lumber-market in the State, and one of the largest in the west, and has numerous manufacturing establishments. The northern State prison (with 577 convicts at the close of 1880) is one of the principal buildings. The population increased from 3985 in 1870 to over 10,000 in 1883.

MICHMASH (מִכְמָשׂ, מִכְמָס), the scene of one of the most striking episodes in Old Testament history (1 Sam. xiv., comp. vol. xii. p. 403), was a place in Benjamin, about 9 Roman miles north of Jerusalem (*Onom.*, ed. Lag., p. 280). Though it did not rank as a city (Josh. xviii. 21 *sq.*), Michmash was recolonized after the exile (Neh. xi. 31), and, favoured by the possession of excellent wheat-land (*Mishna*, Men. viii. 1), was still a very large village (Μαχμάς) in the time of Eusebius. The modern Makhmás is quite a small place.

The historical interest of Michmash is connected with the strategical importance of the position, commanding the north side of the Pass of Michmash, which made it the headquarters of the Philistines and the centre of their forays in their attempt to quell the first rising under Saul, as it was also at a later date the headquarters of Jonathan the Hasmonæan (1 Mac. ix. 73). From Jerusalem to Mount Ephraim there are two main routes. The present caravan road keeps the high ground to the west near the watershed, and avoids the Pass of Michmash altogether. But another route, the importance of which in antiquity may be judged of from Isa. x. 28 *sq.*, led southwards from Ai over an undulating plateau to Michmash. Thus far the road is easy, but at Michmash it descends into a very steep and rough valley, which has to be crossed before reascending to Geba.[1] At the bottom of the valley is the Pass of Michmash, a noble gorge with precipitous craggy sides. On the north the crag is crowned by a sort of plateau sloping backwards into a round-topped hill. This little plateau, about a mile east of the present village of Makhmás, seems to have been the post of the Philistines, lying close to the centre of the insurrection, yet possessing unusually good communication with their establishments on Mount Ephraim by way of Ai and Bethel, and at the same time commanding the routes leading down to the Jordan from Ai and from Michmash itself.

MICKIEWICZ, ADAM (1798–1855), Polish poet, was born in 1798, near Nowogrodek, in the present government of Minsk, where his father, who belonged to the schlachta or lesser nobility, had a small property. The poet was educated at the university of Vilna; but, becoming involved in some political troubles there, he was forced to terminate his studies abruptly, and was ordered to live for a time in Russia. He had already published two small volumes of miscellaneous poetry at Vilna, which had been favourably received by the Slavonic public, and on his arrival at St Petersburg he found himself admitted to the leading literary circles, where he was a great favourite both from his agreeable manners and his extraordinary talent of improvisation. In 1825 he visited the Crimea, which inspired a collection of sonnets in which we may admire both the elegance of the rhythm and the rich Oriental colouring. The most beautiful are *The Storm*, *Bakchi-serai*, and *Grave of the Countess Potocka*.

In 1828 appeared his *Konrad Wallenrod*, a narrative poem describing the battles of knights of the Teutonic order with the heathen Lithuanians. Here, under a thin veil, Mickiewicz represented the sanguinary passages of arms and burning hatred which had characterized the long feuds of the Russians and Poles. The objects of the poem, although evident to many, escaped the Russian censors, and it was suffered to appear, although the very motto, taken from Machiavelli, was significant: "Dovete adunque sapere come sono duo generazioni da combattere . . . bisogna essere volpe e leone." After a five years' exile in Russia the poet obtained leave to travel; he had secretly made up his mind never to return to that country or Poland so long as it remained under the government of the Muscovites. Wending his way to Weimar, he there made the acquaintance of Goethe, who received him cordially, and, pursuing his journey through Germany, he entered Italy by the Splügen, visited Milan, Venice, and Florence, and finally took up his abode at Rome. There he wrote the third part of his poem *Dziady*, the subject of which is the religious commemoration of their ancestors practised among Slavonic nations, and *Pan Tadeusz*, his longest poem, by many considered his masterpiece. A graphic picture is drawn of Lithuania on the eve of Napoleon's expedition to Russia in 1812. In 1832 Mickiewicz left Rome for Paris, where his life was for some time spent in poverty and unhappiness. He had married a Polish lady, Selina Szymanowska, who became insane. In 1840 he was appointed to the newly founded chair of Slavonic languages and literature in the Collége de France, a post which he was especially qualified to fill, as he was now the chief representative of Slavonic literature, Poushkin having died in 1837. He was, however, only destined to hold it for a little more than three years, his last lecture having been given on the 28th of May 1844. His mind had become more and more disordered under the influence of religious mysticism. His lectures became a medley of religion and politics, and thus brought him under the censure of the Government. A selection of them has been published in four volumes. They contain some good sound criticism, but the philological part is very defective, for Mickiewicz was no scholar, and he is obviously only well acquainted with two of the literatures, viz., Polish and Russian, the latter only till the year 1830. A very sad picture of the declining days of Mickiewicz is given in the memoirs of Herzen. At a comparatively early period the unfortunate poet exhibited all the signs of premature old age; poverty, despair, and domestic affliction had wrought their work upon him. In 1849 he founded a French newspaper, *La Tribune des Peuples*, but it only existed a year. The restoration of the French empire seemed to kindle his hopes afresh; his last composition is said to have been a Latin ode in honour of Napoleon III. On the outbreak of the Crimean War he was sent to Constantinople to assist in raising a regiment of Poles to take service against the Russians. He died suddenly there in 1855, and his body was removed to France and buried at Montmorency.

Mickiewicz is held to have been the greatest Slavonic poet, with the exception of Poushkin. Unfortunately in other parts of Europe he is but little known; he writes in a very difficult language, and one which it is not the fashion to learn. There were both pathos and irony in the expression used by a Polish lady to a foreigner, "Nous avons notre Mickiewicz à nous." He is one of the best products of the so-called romantic school. The Poles had long groaned under the yoke of the classicists, and the country was full of legends and picturesque stories which only awaited the coming poet to put them into shape. Hence the great popularity among his countrymen of his ballads, each of them being connected with some national tradition. Besides *Konrad Wallenrod* and *Pan Tadeusz*, attention may be called to the poem *Grazyna*, which describes the adventures of a Lithuanian chieftainess against the Teutonic knights. It is said by Ostrowski to have inspired the brave Emilia Plater, who was the heroine of the rebellion of 1830, and after having fought in the ranks of the insurgents, found a grave in the forests of Lithuania. A fine vigorous Oriental piece is *Farys*. Very good too are the odes to Youth and to the historian Lelewel; the former did much to stimulate the efforts of the Poles to shake off their Russian conquerors. It is enough to say of Mickiewicz that he has obtained the proud position of the representative poet of his country; her customs, her superstitions, her history, her struggles are reflected in his works.

[1] So Isa. x. 28 describes the invader as leaving his heavy baggage at Michmash before pushing on through the pass.

MICKLE, WILLIAM JULIUS (1734–1788), son of the minister of Langholm, Dumfriesshire, holds a respectable place among the imitative minor poets of the 18th century. He wrote a poem on *Knowledge*—carefully versified, pointing a moral on the vanity of intellectual pride—at the age of eighteen, entered into business as a brewer at his father's request and against his own inclinations, soon became bankrupt, went to London on outlook for work as a man of letters, solicited patronage in vain, earned a living hardly by writing for magazines, made some impression in 1765 by "a poem in the manner of Spenser" called the *Concubine* (afterwards *Syr Martyn*), was appointed corrector to the Clarendon Press, and finally took a place among the leading poets of that very barren time by a translation of the *Lusiad* of Camoens into heroic couplets (specimen published 1771, whole work 1775). So great was the repute of the work that when Mickle—appointed secretary to Commodore Johnstone—visited Lisbon in 1779 the king of Portugal gave him a public reception. As a translator of Camoens Mickle has been superseded, but he aimed, not at close rendering of the original, but at making a poem which should be worthy of a permanent place in English literature. This ambition he was not capable of fulfilling, though he had great fluency and vigour. It may be doubted whether the fashionable forms which he imitated were the best suited to his natural gifts. He shows delight in lively action, a sense of dramatic effect, and, in the *Concubine*, the substance of which might have been conceived by Crabbe, considerable fulness of detail in coarse realistic painting. Certainly, if the Scottish poem *There 's nae luck aboot the hoose* was Mickle's, he mistook his medium. Scott read and admired Mickle's poems in his youth, and, besides founding *Kenilworth* on the ballad of *Cumnor Hall*, was a good deal influenced by him in style. Mickle's prose is lively and vigorous.

MICROMETER, an instrument generally applied to telescopes and microscopes for measuring small angular distances with the former or the dimensions of small objects with the latter.

Before the invention of the telescope the accuracy of astronomical observations was necessarily limited by the angle that could be distinguished by the naked eye. The angle between two objects, such as stars or the opposite limbs of the sun, was measured by directing an arm furnished with fine "sights" (in the sense of the "sights" of a rifle) first upon one of the objects and then upon the other, or by employing an instrument having two arms each furnished with a pair of sights, and directing one pair of sights upon one object and the second pair upon the other. The angle through which the arm was moved, or, in the latter case, the angle between the two arms, was read off upon a finely graduated arc. With such means no very high accuracy was possible. Archimedes concluded from his measurements that the sun's diameter was greater than 27′ and less than 32′; and even Tycho Brahe was so misled by his measures of the apparent diameters of the sun and moon as to conclude that a total eclipse of the sun was impossible.[1] Maestlin in 1579 determined the relative positions of eleven stars in the Pleiades (*Historia Cœlestis Lucii Baretti*, Augsburg, 1666), and Winnecke has shown (*Monthly Notices R. A. S.*, vol. xxxix. p. 146) that the probable error of these measures amounted to about ±2′.[2]

[1] Grant, *History of Physical Astronomy*, p. 449.

[2] This is an astonishing accuracy when the difficulty of the objects is considered. Few persons can see with the naked eye—much less measure—more than six stars of the Pleiades, although all the stars measured by Maestlin have been seen with the naked eye by a few individuals of exceptional powers of eye-sight.

The invention of the telescope at once extended the possibilities of accuracy in astronomical measurements. The planets were shown to have visible disks, and to be attended by satellites whose distance and position angle relative to the planet it was desirable to measure. It became, in fact, essential to invent a "micrometer" for measuring the small angles which were thus for the first time rendered sensible. There is now no doubt that William Gascoigne, a young gentleman of Yorkshire, was the first inventor of the micrometer. Crabtree, a friend of his, taking a journey to Yorkshire in 1639 to see Gascoigne, writes thus to his friend Horrocks. "The first thing Mr Gascoigne showed me was a large telescope amplified and adorned with inventions of his own, whereby he can take the diameters of the sun and moon, or any small angle in the heavens or upon the earth, most exactly through the glass, to a second." The micrometer so mentioned fell into the possession of Mr Richard Townley of Lancashire, who exhibited it at the meeting of the Royal Society held on the 25th July 1667.

Gascoigne's micrometer.

The principle of Gascoigne's micrometer is that two pointers, having parallel edges at right angles to the measuring screw, are moved in opposite directions symmetrically with and at right angles to the axis of the telescope. The micrometer is at zero when the two edges are brought exactly together. The edges are then separated till they are tangent to the opposite limbs of the disk of the planet to be measured, or till they respectively bisect two stars, the angle between which is to be determined. The symmetrical separation of the edges is produced and measured by a single screw; the fractions of a revolution of the screw are obtained by an index attached to one end of the screw, reading on a dial divided into 100 equal parts. The whole arrangement is elegant and ingenious. A steel cylinder (about the thickness of a goose-quill), which forms the micrometer screw, has two threads cut upon it, one-half being cut with a thread double the pitch of the other. This screw is mounted on an oblong box which carries one of the measuring edges; the other edge is moved by the coarser part of the screw relatively to the edge attached to the box, whilst the box itself is moved relatively to the axis of the telescope by the finer screw. This produces an opening and closing of the edges symmetrically with respect to the telescope axis. Flamsteed, in the first volume of the *Historia Cœlestis*, has inserted a series of measurements made by Gascoigne extending from 1638 to 1643. These include the mutual distances of some of the stars in the Pleiades, a few observations of the apparent diameter of the sun, others of the distance of the moon from neighbouring stars, and a great number of measurements of the diameter of the moon. Dr Bevis (*Phil. Trans.*, 1773, p. 190) also gives results of measurements by Gascoigne of the diameters of the moon, Jupiter, Mars, and Venus with his micrometer.

Delambre gives[3] the following comparison between the results of Gascoigne's measurements of the sun's semi-diameter and the computed results from modern determinations:—

	Gascoigne.	*Conn. d. Temps.*
October 25 (O.S.)	16′ 11″ or 10″	16′ 10″·0
,, 31 ,, ...	16′ 11″	16′ 11″·4
December 2 ,, ...	16′ 24″	16′ 16″·8

Gascoigne, from his observations, deduces the greatest variation of the apparent diameter of the sun to be 35″; according to the *Connaissance des Temps* it amounts to 32″·3.[3] These results prove the enormous advance attained in accuracy by Gascoigne, and his indisputable title to the credit of inventing the micrometer.

Huygens, in his *Systema Saturnium* (1659), describes a micrometer with which he determined the apparent

[3] Delambre, *Hist. Ast. Moderne*, vol. ii. p. 590.

diameters of the principal planets. He inserted a slip of metal, of variable breadth, at the focus of the telescope, and observed at what part it exactly covered the object under examination; knowing the focal length of the telescope and the width of the slip at the point observed, he thence deduced the apparent angular breadth of the object. The Marquis Malvasia in his *Ephemerides* (Bologna, 1662) describes a *micrometer* of his own invention. At the focus of his telescope he placed fine silver wires at right angles to each other, which, by their intersection, formed a network of small squares. The mutual distances of the intersecting wires he determined by counting, with the aid of a pendulum clock, the number of seconds required by an equatorial star to pass from web to web, while the telescope was adjusted so that the star ran parallel to the wires at right angles to those under investigation.[1] In the *Phil. Trans.*, 1667, No. 21, p. 373, Auzout gives the results of some measures of the diameter of the sun and moon made by himself, and this communication led to the letters of Mr Townley and Dr Bevis above referred to. The micrometer of Auzout and Picard was provided with silk fibres or silver wires instead of the edges of Gascoigne, but one of the silk fibres remained fixed while the other was moved by a screw. It is beyond doubt that Huygens independently discovered that an object placed in the common focus of the two lenses of a Kepler telescope appears as distinct and well-defined as the image of a distant body; and the micrometers of Malvasia, Auzout, and Picard are the natural developments of this discovery. Gascoigne was killed at the battle of Marston Moor on the 2d July 1644, in the twenty-fourth year of his age, and his untimely death was doubtless the cause that delayed the publication of a discovery which anticipated, by twenty years, the combined work of Huygens, Malvaison, Auzout, and Picard in the same direction.

Spider webs. As the powers of the telescope were gradually developed, it was found that the finest hairs or filaments of silk, or the thinnest silver wires that could be drawn, were much too thick for the refined purposes of the astronomer, as they entirely obliterated the image of a star in the more powerful telescopes. To obviate this difficulty Professor Felice Fontana of Florence (*Saggio del real gabinetto di fisica e di storia naturale*, 1755) first proposed the use of spider webs in micrometers,[2] but it was not till the attention of Troughton had been directed to the subject by Rittenhouse that the idea was carried into practice.[3] In 1813 Wollaston proposed fine platinum wires, prepared by surrounding a platinum wire with a cylinder of silver, and drawing out the cylinder with its platinum axis into a fine wire.[4] The surrounding silver was then dissolved by nitric acid, and a platinum wire of extreme fineness remained. But experience soon proved the superiority of the spider web; its perfection of shape, its lightness and elasticity, have led to its universal adoption.

Beyond the introduction of the spider line it is unnecessary to mention the various steps by which the Gascoigne micrometer assumed the modern forms now in use, or to describe in detail the suggestions of Hooke,[5] Wren, Smeaton, Cassini, Bradley, Maskelyne, Herschel, Arago, Pearson, Bessel, Struve, Dawes, &c., or the successive productions of the great artists Ramsden, Troughton, Fraunhofer, Ertel, Simms, Cooke, Grubb, Clarke, and Repsold. It will be sufficient to describe those forms with which the most important work has been done, or which have survived the tests of time and experience.

Position angles. Before astronomical telescopes were mounted parallactically, the measurement of position angles was seldom attempted. Indeed, in those days, the difficulties attached to such measures, and to the measurement of distances with the filar micrometer, were exceedingly great, and must have taxed to the utmost the skill and patience of the observer. For, on account of the diurnal motion, the direction of the axis of the telescope when directed to a star is always changing, so that, to follow a star with an altazimuth mounting, the observer requires to move continuously the two handles which give slow motion in altitude and azimuth.

Herschel's instrument. Sir William Herschel was the first astronomer who measured position angles; the instrument he employed is described in *Phil. Trans.*, 1781, vol. lxxi. p. 500. It was used by him in his earliest observations of double stars (1779-83); but, even in his matchless hands, the measurements were comparatively crude, because of the difficulties he had to encounter from the want of a parallactic mounting. In the case of close double stars he estimated the distance in terms of the disk of the components. For the measurement of wider stars he invented his lamp-micrometer, in which the components of a double star observed with the right eye were made to coincide with two lucid points placed 10 feet from the left eye. The distance of the lucid points was the tangent of the magnified angles subtended by the stars to a radius of 10 feet. This angle, therefore, divided by the magnifying power of the telescope gives the real angular distance of the centres of a double star. With a power of 460 the scale was a quarter of an inch for every second.

The Modern Filar Micrometer.

When equatorial mountings for telescopes became more general, no filar micrometer was considered complete which was not fitted with a position circle.[6] The use of the spider line or filar micrometer became universal; the methods of illumination were improved; and micrometers with screws of previously unheard-of fineness and accuracy were produced. These facilities, coupled with the wide and fascinating field of research opened up by Sir William Herschel's discovery of the binary character of double stars, gave an impulse to micrometric research which has continued unabated to the present time. A still further facility was given to the use of the filar micrometer by the introduction of clockwork, which caused the telescope automatically to follow the diurnal motion of a star, and left the observer's hands entirely at liberty.[7]

Classification of micrometers. The modern filar micrometer has now assumed forms of five types.

Type A.—Micrometers in which there are two webs, each movable by a fine screw with a divided head. This is the usual English form of filar micrometer.

Type B.—Micrometers in which one web is movable by means of a fine screw with a divided head, and the other by a screw without a divided head. The latter screw, in ordinary use, is only employed to change the coincidence-reading of the two webs, for eliminating the errors of the micrometer screw. This is the ordinary German form of micrometer as originally made by Fraunhofer and since by Merz, and employed by the Struves and other principal Continental astronomers down to the present day.

Type C.—A similar form of micrometer to B, except that the coincidence-point cannot be changed,—there being no second screw to alter the position of the fixed web.

Type D.—A micrometer somewhat similar in general construction to form B, except that, in addition to means of changing the zero point, there is a screw head by which a fine movement can be given to the whole micrometer box, in the direction of the axis of the micrometer screw. This is the modern form of micrometer as constructed by Repsold.

Type E.—Micrometers fitted with two eye-pieces for measuring angles larger than the field of view of an ordinary eye-piece.

Troughton's filar micrometer. The micrometer of type A is due to Troughton; it is represented in figs. 1, 2, 3. Fig. 1 is a horizontal section in the direction of the axis of the telescope. The eye-piece *ab* consists of two plano-convex lenses *a*, *b*, of nearly the same focal length, and with the two

[1] *Mém. Acad. des Sciences*, 1717, p. 78 *sq.*

[2] In 1782 (*Phil. Trans.*, vol. lxxii. p. 163) Sir W. Herschel writes:—"I have in vain attempted to find lines sufficiently thin to extend them across the centres of the stars, so that their thickness might be neglected." It is a matter of regret that Fontana's suggestion was unknown to him.

[3] Quekett in his *Treatise on the Microscope* ascribes to Ramsden the practical introduction of the spider web in micrometers. The evidence appears to be in favour of Troughton.

[4] *Phil. Trans.*, 1813, pp. 114-118.

[5] Dr Hooke made the important improvement on Gascoigne's micrometer of substituting parallel *hairs* for the parallel edges of its original construction (Hooke's *Posthumous Works*, p. 497).

[6] Herschel and South (*Phil. Trans.*, 1824, part iii. p. 10) claim that the micrometer by Troughton, fitted to their 5-feet equatorial telescope, is the first position micrometer constructed capable of measuring position angles to 1′ of arc.

[7] So far as we can ascertain, the first telescope of large size driven by clockwork was the 9-inch equatorial made for Struve at Dorpat by Fraunhofer; it was completed in 1825. The original idea appears to be due to Passement (*Mém. Acad.*, Paris, 1746). In 1757 he presented a telescope to the king, so accurately driven by clockwork that it would follow a star all night long.

convex sides facing each other. They are placed at a distance apart less than the focal length of *a*, so that the wires of the micrometer, which must be distinctly seen, are beyond *b*.[1] The eye-piece slides into the tube *cd*, which screws into the brass ring *ef*, through two openings in which the oblong frame, containing the micrometer slides, passes. These slides are shown in fig. 2, and consist of brass forks *k* and *l*, into which the ends of the screws *o* and *p* are rigidly fitted. The slides are accurately fitted so as to have no sensible lateral shake, but yet so as to move easily in the direction of the greatest length of the micrometer box. Motion is communicated to the forks by female screws tapped in the heads *m* and *n*

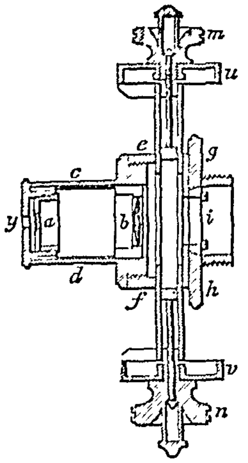

Fig. 1.

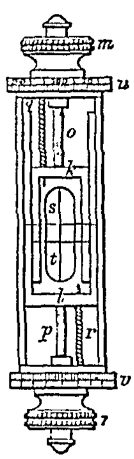

Fig. 2.

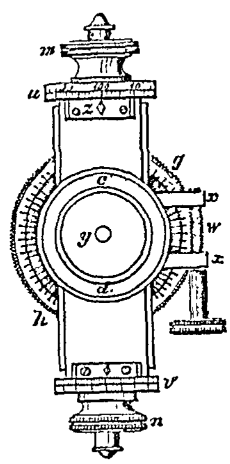

Fig. 3.

acting on the screws *o* and *p* respectively. Two pins *q*, *r*, with spiral springs coiled round them, pass loosely through holes in the forks *k*, *l*, and keep the bearings of the heads *m* and *n* firmly pressed against the ends of the micrometer box. Thus the smallest rotation of either head communicates to the corresponding slide motion, which, if the screws are accurate, is proportional to the amount through which the head is turned. Each head is graduated into 100 equal parts on the drums *u* and *v*, so that, by estimation, the reading can easily be carried to $\frac{1}{1000}$th of a revolution. The total number of revolutions is read off by a scale attached to the side of the box, but not seen in the figure.

Two spider webs are stretched across the forks, one (*t*) being cemented in a fine groove cut in the inner fork *k*, the other (*s*) in a similar groove cut in the outer fork *l*. These grooves are simultaneously cut *in situ* by the maker, with the aid of an engine capable of ruling fine straight lines, so that the webs when accurately laid in the grooves are perfectly parallel. A wire *st* is stretched across the centre of the field, perpendicular to the parallel wires. Each movable web must pass the other without coming in contact with it or the fixed wire, and without rubbing on any part of the brass-work. Should either fault occur (technically called "fiddling") it is fatal to accurate measurement. One of the most essential points in a good micrometer is that all the webs shall be so nearly in the same plane as to be well in focus together under the highest powers used, and at the same time absolutely free from "fiddling." For measuring position angles a brass circle *gh* (fig. 3), fixed to the telescope by the screw *i*, has rack teeth on its circumference that receive the teeth of an endless screw *w*, which, being fixed by the arms *xx* to the oblong box *mn*, gives the latter a motion of rotation round the axis of the telescope; an index upon this box points out on the graduated circle *gh* the angular rotation of the instrument.

The English micrometer still retains the essential features of Troughton's original construction above described. The later English artists have somewhat changed the mode of communicating motion to the slides, by attaching the screws permanently to the micrometer head and tapping each micrometer screw into its slide. Instead of making the shoulder of the screw a flat bearing surface, they have given the screw a spherical bearing resting in a hollow cone (fig. 4) attached to the end of the box. The French artists still retain Troughton's form. Simms (Troughton's successor) and Cooke (of York), for symmetry and more effectual elimination of "the loss of time" (called by the Germans "todter Gang," and sometimes in English "back-lash"), have provided two pins with spiral springs,

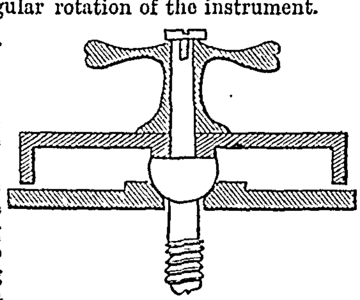

Fig. 4.

like *q* and *r* (fig. 2), one on each side of the screw which moves each slide.

Grubb of Dublin, with the intention of avoiding the variation of pressure exerted by the spiral springs when the slide is at different distances from the head of the screw, has adopted the following plan. Where the screw enters the slide he has a nut *n* attached to a strong spring *pp* (fig. 5), the pressure of which exerts a constant tension in the axis of the screw, tending to bring the threads into close contact, in opposite directions, with their bearings in the nut *n* and the slide *q*. The pressure of this spring is regulated by the screws *s*, *s*, tapped into the thickened ends of the springs. For maintaining the spherical shoulder of the screw in close and constant pressure on its conical bearing he has attached a conical bearing to the spring *p′p′* (fig. 6). The pressure of this on the upper part of the spherical shoulder is regulated by the screws *s′*, *s′*, passing through elongated holes in the spring *p′p′*, and tapped into the end of the box.

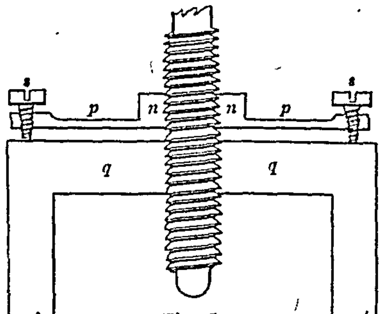

Fig. 5.

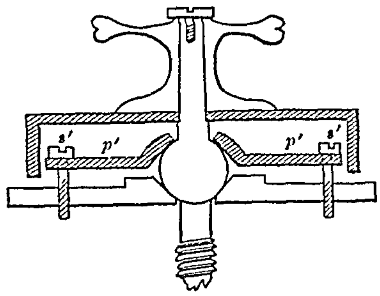

Fig. 6.

The screws of micrometers are generally made with 50 or 100 threads to the inch. Troughton's method of reading the number of whole revolutions by a silver scale is inconvenient, because $\frac{1}{100}$th or even $\frac{1}{50}$th of an inch is too small a quantity to read easily with the naked eye, especially with the faint illumination that it is desirable to use when measuring faint objects. Different methods, including the "comb" (see below) and various kinds of "counters," have been introduced with more or less success; but recently the Repsolds of Hamburg have contrived a plan at once so simple and so efficient that it will be unnecessary to describe those methods which this plan is certain to supersede (see below, type D). Grubb has introduced a modification in the form of the slides with a view to avoid the friction of one slide against the other. On the inner side of the brass plate which forms the bottom of the box (*i.e.*, the side opposite to the eye-piece) four V-shaped furrows are placed (fig. 7); and at each end of the slides are projections (fig. 8, end view) which fit into these furrows. The slides are kept down in their places by springs attached to them, which press upon the inner side of the lid of the box.

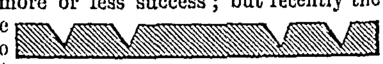

Fig. 7.

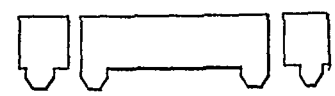

Fig. 8.

Troughton's mode of giving rotation to the position circle is now abandoned. A much quicker motion in position angle than can be obtained without slow motion is often desirable, since, in observing very close double stars, the uncertainty of each pointing may amount to several degrees in the most accurate measurements. The plan of a pinion working in a toothed wheel is often employed, but that also is too slow. Most modern micrometers are now fitted with a clamp and slow motion screw (see fig. 9, type B). This permits observation of position angles of very close objects by simple rotation of the box with the hand; while the slow motion, after clamping, permits the more delicate movements that are required in measuring the position angle of objects farther apart.

The Cookes and Grubb have for years almost invariably transferred the position circle from the micrometer to the telescope tube. The whole eye-end with its focussing arrangements rotates, and its rotation can be measured by a circle attached to the butt end of the tube. There is considerable convenience in this arrangement. One position circle only is required for all the micrometers that may be employed with the instrument; and the orientation of reticulated diaphragms, or the adjustment of the direction of the slit of a spectroscope, may also be accomplished by the same means. But, after a very extended experience of all the various types of existing mountings, the present writer does not hesitate to express a decided preference for a position circle attached to the micrometer and a rigid attachment of the eye-end to the telescope tube,—having never seen an eye-end attached to a position circle on the butt end of the telescope-tube in which, after the wear and tear of a few years,

[1] This is known as Ramsden's eye-piece; it was made originally by him.

some looseness or shake could not be detected. This is a fatal fault, especially in those delicate observations of difference of declination which have latterly formed so prominent a feature in refined micrometric research. On the other hand, in some good old micrometers at the Royal Observatory, Cape of Good Hope, that are fitted with attached *position circles*, there is no trace of shake or wear after fifty years of work.

Fraunhofer's filar micrometer

The micrometer of type B represented in fig. 9[1] is the original Merz micrometer of the Cape Observatory, made on Fraunhofer's model. S is the head of the micrometer screw proper, *s* that of the screw moving the slide to which the so-called "fixed web" is attached, *s'* that of a screw which moves the eye-piece E. C is the clamp and M the slow motion in position angle. L, L are tubes attached to a larger tube N; the latter fits loosely on a strong hollow cylinder which terminates in the screw V. By this screw the whole apparatus is attached to the telescope. The

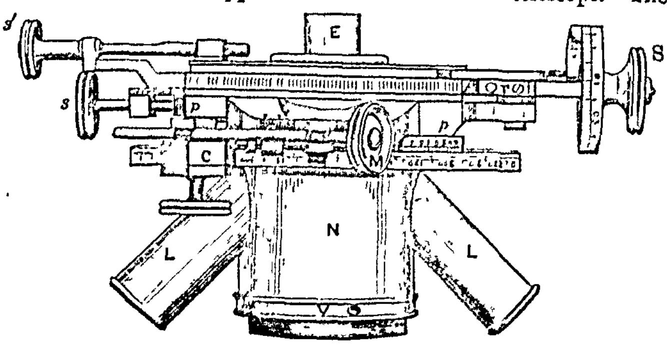

Fig. 9.

nozzles of small lamps are inserted in the tubes L, L, for illuminating the webs in a dark field; the light from these lamps is admitted through apertures in the strong hollow cylinder above mentioned (for illumination, see below). In this micrometer the three slides moved by S, *s*, and *s'* are simple dovetails. The lowest of these slides reposes upon a foundation-plate *pp*, into one end of which the screw *s* is tapped. In the middle of this slide a stiffly fitting brass disk is inserted, to which a small turn-table motion may be communicated by an attached arm, acted on by two fine opposing screws accessible to the astronomer; and by their means the "fixed wire" may be rendered strictly parallel with the movable wire.

The micrometer screw is mounted on the slide which carries the movable web. Fig. 10 shows a plan of this slide; the divided drum of the screw is omitted for sake of clearness. The screw S has a shoulder at κ, carefully fitted and ground to a bearing so as to work sweetly in a hole in the very strong spring $\sigma\sigma$; the other extremity of the screw is formed into a pivot, which fits a hole in the brass piece $\beta\beta$. The end of this pivot—hardened, polished, and slightly rounded—rests on the flat surface of an agate α, which is imbedded in the end of the slide, and kept firmly in its place by the brass piece $\beta\beta$. By careful adjustment of the screws θ, θ sufficient pressure may be left upon κ to slightly bend the strong spring $\sigma\sigma$ and thus eliminate all end-shake without preventing easy action of the screw. The screw passes at the same time through the bush B (shown in plan and elevation, fig. 10) attached to *pp* (fig. 9); and there is a fine saw cut, which can be narrowed by the small screw τ, to close the bush upon the micrometer screw with a view of preventing "loss of time." The spider web ω is cemented on the further side of the thin plate $\nu\nu\nu$, the varnish being applied in the countersunk holes shown by the dotted circles μ, μ. The slide is countersunk to about half its thickness within the area indicated by *oooo*, in order to allow the adapter of the eye-piece to come sufficiently close to the webs. The eye-piece was originally moved by a pinion working in a rack *r* (fig. 9); but the screw *s'* applied by Simms was found by Maclear to be more convenient for the purpose. Beyond this, and the graduation of the edge of the circle with more strongly cut divisions than those originally engraved on the face of the circle, the instrument remains and is figured in its original form. Pistor and Martius (Berlin) have also made excellent instruments of the above type. There is a celebrated micrometer of their make, with which, in the hands of Brunnow at Dunsink (Dublin), some of the most perfect and refined investigations ever made in practical

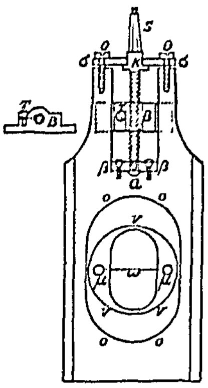

Fig. 10.

Dunsink micrometer.

astronomy have been executed. In this micrometer the screw *s* is mounted on its own slide and has a divided head precisely like the screw S (fig. 9). The plate *pp* is elongated towards *s*, and the corresponding bush B is attached to this elongation. The screw *s'* is shifted to another part of the eye-piece slide, so that it does not interfere with the increased diameter of the screw *s*. Fraunhofer's micrometer in this form belongs to type A, but is quoted under type B for convenience of description.

It is not necessary to give a figure representing type C. Such micrometers have been generally constructed on Troughton's type (figs. 1, 2, 3) with the omission of one of the screws, and with one or more of the modifications described in detail under type A. Some have also been made similar otherwise to the Fraunhofer construction, by omitting the screw *s* with its corresponding slide and attaching the fixed wire to a circular plate in *pp*.

Clark's filar micrometer.

Good instruments have been made on type C by Clark (Cambridge, Massachusetts), by Steinheil (Munich), and by the great French artists Secretan, Froment, Brunner, Eichens; and good work has been done with them. But it is necessary that the errors of the screw should be very carefully determined, since, in type C, such errors cannot be eliminated by employing different parts of the screw to measure the same angle. There is a noteworthy description of micrometer that forms a link between types C and D, of which the most famous example (by Clark) is attached to the great Washington telescope. It is essentially a micrometer of type C, with a slide (or fork) and a screw of the English form of construction. But the instrument is provided with a screw as at *s* (fig. 9), which, instead of changing the position of the fixed wire, moves the whole micrometer box in the direction of the axis of the measuring screw. Thus the fixed wire can be set exactly on one star by the screw *s* while the other star is immediately afterwards bisected by the movable wire, and that without disturbing the reading for coincidence of the wires. No one, unless he has previously worked without such an arrangement, can fully appreciate the advantage of bringing up a star to bisection by the fixed wire by moving the micrometer box with a delicate screw-motion, instead of having to change the direction of the axis of a huge telescope for the same purpose. When it is further remembered that the earlier telescopes were not provided with the modern slow motions in right ascension, and that the Struves, in their gigantic labours among the double stars, used to complete their bisections on the fixed wire by a pressure of the finger on the side of the tube, one is puzzled whether most to wonder at the poor adaptation of means to ends or the marvellous patience and skill which, with such means, led to such results.[2] It should be added that Dawes practically adopted a modification of Clark's micrometer by using a slipping piece, and bolting one of the heads of his micrometer (*Mem. R. A. S.*, vol. xxxv. p. 139). His slipping piece gave motion to the micrometer by two slides, one in right ascension the other in declination, so that "either of the webs can be placed upon either of the components of a double star with ease and certainty."

All micrometers used, in conjunction with a microscope, for reading the divisions of transit circles, heliometer scales, &c., are of the type C. The reading micrometer is shown in fig. 11. C is the objective, D the micrometer box, E the graduated head of the screw, G the milled head by which the screw *cc* is turned, A an eye-piece sliding in a tube B, *aa* (fig. 12) the slide,

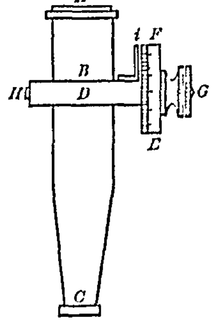

Fig. 11.

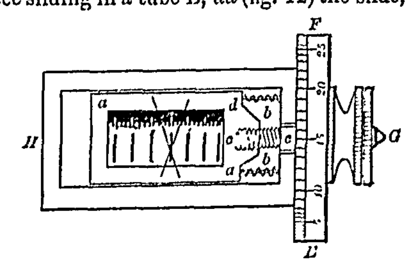

Fig. 12.

and *b*, *b* the spiral springs. The focal length of the objective and the distance between the optical centre of the lens and the webs are so arranged that images of the divisions are formed in the plane of the webs, and the pitch of the screw is such that one division of the scale corresponds with some whole number of revolutions of the screw.

There is what is technically called a "comb" inserted in the micrometer box at *d* (fig. 12),—its upper surface being nearly in the plane of the wires. This comb does not move with reference to the box, and serves to indicate the whole revolution of which a fraction is read on the head. In fig. 12 a division is represented bisected by cross webs, and five revolutions of the screw correspond with one division of the scale. In all modern reading micrometers the cross webs of fig. 12 are replaced by parallel webs embracing the division

[1] When it is remembered that the measurements of the Struves, Dembowski, Secchi, the Bonds, Maclear, and of most modern Continental astronomers have been made with Fraunhofer or Merz micrometers, it is not too much to say that fig. 9 represents the instrument with which three-fourths of the astronomical measurements of the last fifty years have been made.

[2] The late Professor Watson used to say, quaintly and with truth, "After all, the best part of the micrometer is the man at the small end!"

(fig. 13). The means for changing the length of the tube and the distance of C from the scale are omitted in the figure. These appliances are required if the "run" has to be accurately adjusted. By "run" is meant the difference between the intended whole number of screw-revolutions and the actual measure of the space between two adjacent divisions of the scale in turns of the screw divided by the number of intended revolutions. In delicate researches two divisions of the scale should always be read, not merely for increased accuracy but to obtain the corrections for "run" from the observations themselves.

Fig. 13.

Repsold's reading micrometer.

Fig. 14 represents an important type of reading micrometer by the Repsolds. Here the web-frame is mounted on the screw itself. The limiting plane of motion is at *p*, where the end of the micrometer screw bears upon the hardened, flattened end of the screw *s*, and is kept in bearing against this plane by the spiral spring *q*. Rotation

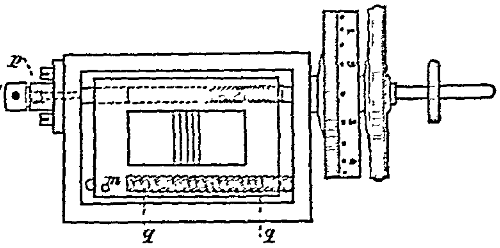

Fig. 14.

of the wire-frame is prevented by the small stud *m* which passes through the web-frame and projects slightly on both sides of it, just barely touching the inner surfaces of the top and bottom of the micrometer box. The web-frame thus rests solely on the screw and on the point *m*, and therefore follows it absolutely and accurately.

Micrometer errors.

The comparative merits of the various micrometers are discussed by Lord Lindsay and Mr Gill (*Dunecht Publications*, vol. ii. pp. 53–55, 1877). If the screw of the Repsold micrometer is bent, so that, for example, the end of the frame next the screw-head is raised and that next the end *p* lowered, a twist will be given to the web-frame, and the centre of the wire will be moved nearer to the micrometer head than it should be, while the reverse effect will follow when the head has been turned through 180°. The effect of a similar error on the other micrometers described would be of a much less amount. They are, however, liable to errors of another character. If, as in Troughton's original micrometer, the shoulder is square, the hole in the end of the box may be left sufficiently wide to allow for a small error in the parallelism of the screw-matrix with the motion of the slide, but the smallest bend in the screw causes the shoulder no longer to bear flat, but to ride on its edge, thus introducing an extremely uncertain form of error. If the shoulder is spherical, fitting into a hollow cone on the end of the box, as in the micrometers of Simms, Cooke, and Grubb, an almost inconceivable accuracy of construction is implied in drilling the matrix of the screw in the slide so that its axis and that of the cone shall be in the same straight line, and both parallel to the motion of a point in the slide. Any departure from perfect accuracy in this respect has the effect of bringing different portions of the spherical shoulder to bear on different parts of the cone for different revolutions, and introduces errors of a character by no means easy to deal with. In addition to these objections there always is the greater objection of employing as a delicate contact-measuring surface one that is exposed where oil is used. Dust and oil will arrange themselves in layers of variable and uncertain thickness and defeat all attempts to secure absolutely consistent results. In Repsold's micrometer the *point d'appui* is a small hardened and polished bearing, requiring little lubrication, and perfectly protected from dust; the errors of the screw (some of them exaggerated, certainly) are faithfully reproduced, and consequently determinable, and beyond this the work to be done by the screw is reduced to a minimum,—no slide-friction having to be overcome. If we are to regard as the most perfect instrument, "not that which has absolutely the smallest errors, but that which reproduces its errors with the most perfect consistency," undoubtedly Repsold's form of micrometer is best.

In order to avoid the exaggeration of the screw-errors produced by the non-symmetrical position of the screw in Repsold's micrometer, Stone, in December 1879, exhibited at the Royal Astronomical Society, and described (*Monthly Notices*, p. 270), a modification of Repsold's instrument. But, both in his statement of the comparative merits of the Troughton and Repsold micrometers and in the new form which he figures, Stone overlooks a strong point in the Repsold form, and in that proposed by Lord Lindsay and Gill three years previously,[1]—namely, the avoidance of all friction of the slide, and the elimination of all error or strain that may occur from a want of parallelism in the axis of the matrix and the motion of the slide.

Lindsay-Gill micrometer.

The Lindsay-Gill micrometer will be better understood from the following description. In fig. 15 S*s* is the micrometer screw; its cylindrical axis is nicely ground to fit a hole in the side of the box at *a*;[2] the same axis, but ground to a somewhat smaller cylinder, fits neatly but smoothly a hole in the web-frame at *b*. A screw, cut on the same axis, is tapped into the web-frame at *s*, and the axis terminates in a pivot which fits a hole in a brass plate *cc*. The end of the pivot—hardened and slightly rounded —rests on a flat agate[3] bearing *a*, which is imbedded in the plate B, and securely held *in situ* by pressure of the plate *cc*. The plate B is firmly attached to the bottom of the box. *q*, *q* are spiral springs mounted on pins. Both springs and pin pass freely through the web-frame at *p*, *p*, and the pins (but not the springs) pass freely through the frame at *n*, *n*.[4] The parallel webs for observing the division (fig. 13) are mounted on the forked end of the frame at *ww*.

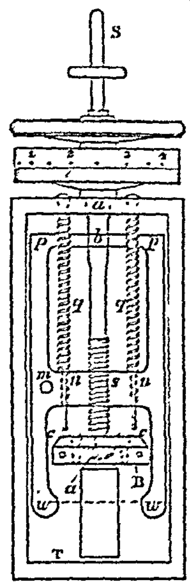

Fig. 15.

The web-frame is narrower and thinner than the breadth and height of the interior of the box, and is only prevented from rotating by the delicate touch of the projecting ends of the pin *m* on the inner surfaces of the top and bottom of the box. It appears that a frame so mounted fulfils all theoretical conditions of accuracy. It is perfectly free to follow the motion of the screw and accurately to reproduce its errors, notwithstanding any reasonable faults of workmanship; and no permissible shake or fouling of the bearing at *a* can produce sensible error in the distance between the bearing surface of the agate plane and the spider webs. The motion is produced with the minimum of friction; and the "feel" of the screw is therefore as delicate and perfect as it is possible to make it.

Repsold's micrometer.

The micrometer of type D shown in fig. 16 has recently been made by the Repsolds for the Cape Observatory. As this instrument combines all their most recent modifications, we describe it in detail. Fig. 17 represents the same micrometer with the upper side of the box removed. The letters in the description refer to both figures.

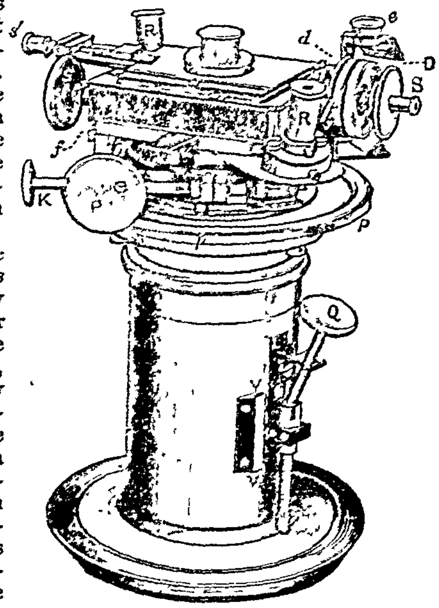

Fig. 16.

S is the head of the micrometer screw, *s* that of the screw by which the micrometer box is moved relative to the plate *f* (fig. 16), *s'* that of the screw which moves the eye-piece slide. K is the clamp in position angle, P the slow motion screw in position angle; *pp* is the position circle, R, R its two readers. The latter are in fact little microscopes carrying a vernier etched on glass, in lieu of a filar micrometer. These verniers can be read to 1′, and estimated to 0′·2. D is the drum-head which gives the fraction of a revolution, *d* that which gives the whole number of revolutions, I is the index or pointer at which both drums are read. This index is shown in fig. 17, but only its mode of attachment (X, fig. 17) in fig. 16. The teeth of the pinion *z*, fig. 17, are cut on the axis of the micrometer screw. The drum *d* and its attached tooth-wheel are ground to turn smoothly on the axis of the screw. The pinion *z* and the toothed wheel *d* are connected by an intermediate wheel and pinion Y; the numbers of teeth in the wheels and pinions are so proportioned that twenty-four revolutions of the micrometer screw produce one revolution of the drum and wheel *d*. (This is the description of Repsold's counter referred to under type A.) The divisions of both drums are conveniently read, simultaneously, by

[1] *Dunecht Publications*, vol. ii., footnote p. 55, Dunecht, 1877.

[2] There would be some advantage in allowing the screw's axis to pass with a little shake through the hole in the end of the box at *a*, and then, extending the length of the larger cylinder, transfer the bearing from *a* to a well-fitting hole in a piece fixed like B to the bottom of the box. This form would also give some facilities of construction, and all the oiled surfaces would be perfectly protected.

[3] Sapphire is better; the agate bearing of such a screw has been found very sensibly worn.

[4] If it is desired to prevent possible contact of these pins with the frame, the ends of the pins may be made to enter guiding holes in *cc*.

the lens e; at night the lamp which illuminates the webs and the position circle also illuminates the drum-heads (see on illumination below). $aaaa$ is the web-frame (fig. 17), $\beta\gamma$ is a single rod consisting of two cylinders accurately fitting in the ends of the micrometer box, the larger cylinder being at β. There is a hole in the web-frame which smoothly fits the larger cylinder at β', and another which similarly fits the smaller cylinder at γ'. A spiral spring, coiled round the cylinder γ, resting one end on the shoulder formed by the difference of the diameters of the cylinders β and γ and the other on the inside of the web-frame, presses the latter continuously towards γ. Contact of the web-frame of the micrometer with the side of the box at γ would therefore take place, were it not for the micrometer screw. This screw fits neatly in the end of the box at ϵ, passes loosely through the web-frame at ϵ', is tapped into the frame at ζ', and its end rests on a flat hardened surface at ζ. Rotation of the web-frame about $\beta\gamma$ is prevented by the heads of the screws at m; the head of the screw on the lower side of the frame reposes on the plane $\nu\nu$, that on the upper side (fig. 17) touches lightly on the inner surface of the lid of the box. Such rotation can obviously be controlled within limits that need not be further considered. But freedom of rotation in the plane of the paper

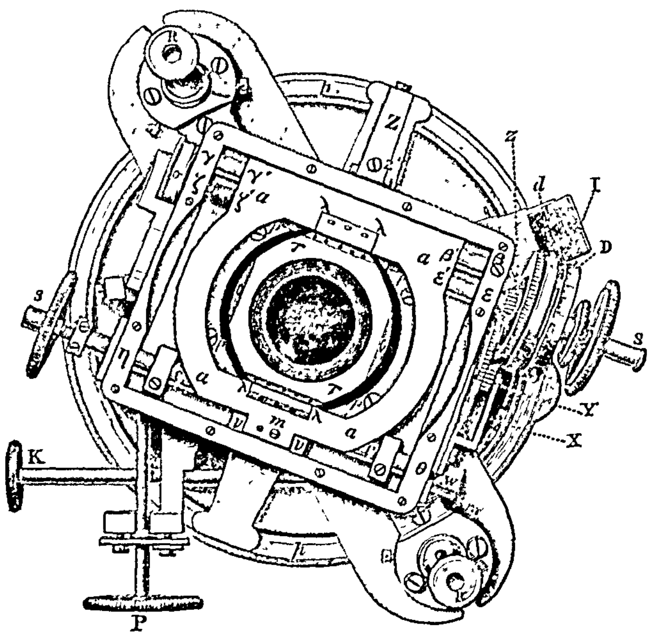

Fig. 17.

(fig. 17) is only prevented by good fitting of the holes β', γ'; and, since the weight of the slide is on one side of the screw, misfit here will have the effect of changing the reading for coincidence of the movable with the fixed web in reverse positions of the micrometer. With the Cape micrometer a systematic difference has been found in the coincidence point for head above and head below amounting to 0''·14. This corresponds, in the Cape instrument, with an excess of the diameters of the holes over those of the cylinders of about $\frac{1}{16000}$th of an inch,—a quantity so small as to imply good workmanship, though it involves a systematic error which is very much larger than the probable error of a single determination of the coincidence point. The obvious remedy is to make all measures on opposite sides of the fixed web before reversing in position angle,—a precaution, however, which no careful observer would neglect. In measuring differences of declination, where the stars are brought up by the diurnal motion, this precaution cannot be adopted, because it is necessary always to bisect the preceding star with the fixed web. But in $\Delta\delta$ measures index error can always be eliminated by bisecting both stars with the same web (or different webs of known interval fixed on the same frame), and not employing the fixed web at all. Had the spring q been placed as in fig. 14, and the cylinders β and γ been made to bear like the pivots of a transit on segmental bearings in the frame at β' and γ', it is probable that the difference in coincidence points would not have existed. Such a modification appears advisable, unless this construction, by leaving the end m less free, should make the "feel" of the screw less sweet and perfect. The discordance in zero when known to exist is really of no consequence, because the observations can be so arranged as to eliminate it.

The box is mounted on a strong hollow steel cylinder CC (fig. 17) by holes η, θ in the ends of the box, which fit the cylinder closely and smoothly. The cylinder is rigidly fixed in the studs C, C, and these are attached to the foundation plate f. The cylinder contains towards η a sliding rod, and towards θ a compressed spiral spring. There is thus a thrust outwards of the spring upon the hollow cap W (attached outside the box), and a thrust of the rod upon the end of the screw s. The position of the box relative to the plate f, in the direction of measurement, depends therefore on the distance between the end of the screw s and the fixed stud C. A screwing in of s thus causes the box to move to the left, and *vice versa*. Rotation of the box round CC is prevented by downward pressure of the spring Z on a projection attached to the side of the box. The amount of this pressure is regulated by the screw z'.

The short screw whose divided milled head is σ shifts the zero of the micrometer by pushing, without turning, the short sliding rod whose flat end forms the *point d'appui* of the micrometer screw at ζ. The pitch of the screw σ is the same as that of the measuring screw (50 threads to the inch), and its motion can be limited by a stop to half a revolution.

The five fixed webs are attached to the table $\tau\tau$, which is secured to the bottom of the box by the screws ρ. The three movable webs are attached to the projections $\lambda\lambda$ on the frame aa. The plane surfaces $\tau\tau$ and $\lambda\lambda$ are composed of a bronze of very close texture, which appears capable of receiving a finish having almost the truth and polish of an optical surface. It seems also to take a very clean V cut, as the webs can be laid in their furrows with an astonishing ease and precision. These furrows have apparently been cut *in situ* with a very accurate engine; for not the slightest departure from parallelism can be detected in any of the movable webs relative to the fixed webs. Extraordinary care has evidently been bestowed in adjusting the parallelism and distance of the planes τ and λ, so that the movable wires shall almost, but not quite, touch the surface τ. The varnish to fix the webs is applied, not on the surface τ as is usual, but on a bevel for the purpose,[1] the position of the webs depending on their tension to keep them in their furrows. The result is that no trace of "fiddling" exists, and the movable and fixed webs come sharply together in focus with the highest powers. Under such powers the webs can be brought into apparent contact with such precision and delicacy that the uncertainty of measurement seems to lie as much in the estimation of the fraction of the division of the head as in the accuracy of the contact. It is a convenient feature in Repsold's micrometer that the webs are very near the inner surface of the top of the box, so that the eye is not brought inconveniently close to the plate when high powers are used.

Micrometers of the type E have been invented by Alvan Clark and Grubb. Clark's micrometer was exhibited at the June meeting of the Royal Astronomical Society in 1859 (*Monthly Notices R. A. S.*, vol. xix.). It is capable of measuring angles up to about one degree. It is "furnished with two eye-pieces, composed of small single lenses, mounted in separate frames, which slide in a groove and can be separated to the required distance. A frame carrying two parallel spider lines, each mounted separately with its own micrometer screw, slides in a dovetailed groove in front of the eye-pieces; and by a free motion in this frame each web can be brought opposite its own eye-lens. In using this micrometer, the first step is to set the position-vernier to the approximate position of the objects to be measured. Then the eye-lenses are separated till each is opposite its own object. The frame containing the webs and their micrometer screws is then slid into its place; and the webs, having been separated nearly to their proper distance by their free motion in the frame, are placed precisely on the objects by their fine screws, the observer's eye being carried rapidly from one eye-lens to the other a few times, till he is satisfied of the bisection of each of the objects by its own web. The frame is then removed for reading off the measure by means of an achromatic microscope, on the stage of which it is placed." The advantages which Clark claims are these:— Clark's micrometer for large angles.

"1. Distances can be observed with great accuracy up to about one degree, and the angles of position also.

"2. The webs, being in the same plane, are perfectly free from parallax, and are both equally distinct, however high the magnifying power may be.

"3. The webs are also free from distortion and from colour.

"4. A different magnifying power may be used on each of the objects,—which may be advantageous in comparing a faint comet with a star."

It appears to us that the method of removing a slide in order to measure the interval between the webs is liable to objection, not only because of the risk to the webs, but because the taking of measurements of such a different character with a different instrument is inconvenient and troublesome. It is true that the intervals between the webs could be measured by an assistant, and two or more different slides be employed to save time; but astronomers will probably generally prefer the method introduced by Grubb described below. It is understood that Clark has since improved this instrument by an ingenious arrangement of prisms, which permits both webs, even though separated one degree in a large telescope, to be seen in the same eye-piece. The arrangement is not described, and is said to be, as yet, somewhat troublesome to arrange previous to measurement, though when arranged it gives very good results.

Grubb (*Scientific Proceedings of Royal Dublin Society*) thus describes

[1] The marks of varnish so applied will be seen in fig. 17.

Grubb's duplex micrometer.

what he calls his "duplex micrometer," shown in perspective in fig. 18:—"A plate of glass about $2\frac{1}{2}$ inches square is ruled with twenty-one lines in one direction $\frac{1}{10}$th inch apart, and two lines in the other direction 2 inches apart. The extreme lines of the set therefore form a perfect square of 2 inches. These lines are ruled with exceeding accuracy and care, but provision is left for ascertaining any errors that remain either as to distance or want of perfect squareness. Along one side of the square is mounted a micrometer frame in the ordinary way, actuated by a screw of one hundred threads to the inch. This micrometer frame carries eleven lines corresponding exactly to each alternate line in the glass reticule, so that when the first spider line is made coincident with the first diamond line on the glass the last spider line will be coincident with the last line on the glass, and each of the spider lines will be coincident with all the odd numbers of diamond lines, 1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21. Over this glass plate is placed a brass cap in which two eye-pieces are mounted, one sliding in a groove at right angles to the other,—so that, while one has its journey backwards and forwards on the horizontal line, the other has its journey on the vertical line, according to how the cap is placed, for this cap is capable of rotation to meet various circumstances.

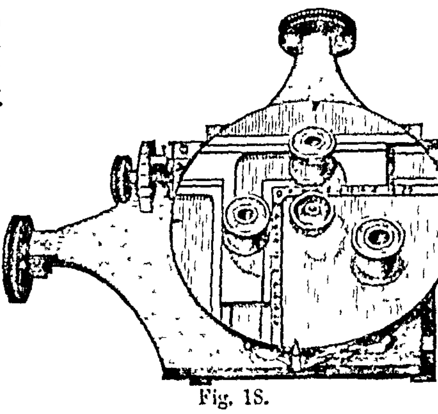

Fig. 18.

"*How to Use the Instrument.*—1. The two stars are brought on the horizontal line, and the distance measured from centre to centre along that line. This distance is measured by counting the number of spaces on the glass, adding the residue as measured by the micrometer screw. Thus the screw is never used for larger measures than $\frac{1}{10}$th inch, and therefore errors of screw and temperature errors are much reduced. In bisecting, one star is brought into the field of one eye-piece, and a bisection is made with one of the diamond lines by moving the micrometer by one or other of its slipping piece screws. Then the other eye-piece is moved till the second star is seen, and a bisection is made with the nearest spider line by moving the micrometer head. Then the eye can be moved back to the first eye-piece, and the bisection checked, and again back to the other eye-piece. When it is seen that both are satisfactory the measure can be read off. 2. The micrometer is turned round till the horizontal line becomes parallel to the path of apparent motion of the star. This is easily found by stopping the clock and allowing the star to run along the horizontal wire. Now the other star will be found to cross the vertical line somewhere, while the first star is on the horizontal line. This second star is then bisected on the vertical line, while the first star is bisected by one of the spider lines; thus the difference in right ascension is found. We then have two sides of a right-angled triangle and of course all the elements are known.

"*To Ascertain the Errors* (*if any*) *of the Distance of the Lines.*—Of course, the usual plan of taking transits can be adopted, and to ascertain if the lines be perfectly at right angles a special additional eye-piece is provided, so that transits can be taken across each diagonal of the square."

This instrument has great advantage over Clark's in case of adjustment and use, and has done good work at the University Observatory, Oxford (*Mem. R. A. S.*, vol. xlvii. pp. 5–12). Professor Pritchard claims too much when he estimates its work as equal in accuracy with that of the heliometer—at least the published results do not confirm such a view. But it is a very valuable instrument for measuring objects too faint for the limited aperture of most heliometers, and which at the same time are farther apart than the field of view of an ordinary eye-piece.

The accuracy of the duplex micrometer would be very greatly increased if Clark's idea (above mentioned) of viewing both widely separated webs in one eye-piece of high power could be reduced to a convenient practical form.

Method of Webbing the Filar Micrometer.

The webbing of a micrometer is a process that should be familiar to all practical astronomers. English opticians usually proceed as follows. A spider (the variety is marked by a cross on the back, and is found in English gardens about decayed wood) is caught, and placed on a wire fork. The insect immediately attaches a web to the wire and begins to lower itself by a web to the ground. This web is wound up on the fork till ten or twelve turns, separated by a convenient space, have been secured. A brush with varnish is then passed along the prongs; the webs are thus securely fixed to the fork. The parallel prongs of the fork must be sufficiently far apart to allow the web-frame of the micrometer to pass between them. The frame to be webbed is placed on a flat dull black surface between the prongs of the fork, the latter being carefully arranged so that one of the webs lies nearly in the furrow ruled in the frame for its reception. As the web-frame is generally thicker than the fork, the web will now be stretched across the former, with a certain amount of tension, and is brought into the furrow with a finely pointed piece of soft wood. If the surface of the frame is well polished, and the furrows sharply cut, without "burr," the web should leap sharply and decidedly into its place. Each end of the web is then secured by a drop of shellac varnish, which should be allowed to harden thoroughly before the frame is touched. The webs can be very readily so handled against a black background, with the aid of a hand lens of 2 or 3 inches focus. In experienced hands this method gives good results, but the following, which is generally followed on the Continent, is preferable.

A web, about 2 inches longer than the width of the frame, is unwound from a cocoon,[1] and small pieces of lead are attached to its extremities by beeswax. One end of the web, with its attached lead, is laid on a piece of cork floating in a tumbler of water; the other end is allowed to hang down in the water, where it becomes thoroughly saturated and untwisted. It is then laid across the fork, and dropped into its furrows in the manner above described, the little lead weights exerting a definite tension. Varnish[2] is immediately applied to secure the webs, and the frame is not touched till it is dry.

The bevel-edge of the web-frame introduced by Repsold (type D) offers great facilities for accurate webbing, and should be employed in all future micrometers.

Illumination of Micrometers.

When micrometer observations are made by night it is necessary to have some mode of rendering the webs visible,—either by rays of light at right angles to the axis illuminating the webs, or by rays nearly coincident with the axis of the telescope. In the former case we get bright webs in a dark field, in the latter dark webs on a bright field.

In the older telescopes bright web illumination is produced by small lamps with nozzles that enter the tubes L, L (fig. 9). The illumination is regulated in colour and intensity by wedges of coloured or darkened glass passing through slides in the nozzles. But it is inconvenient to have lamps so near the observer's eye, and it is at least very difficult to obtain a perfectly dark field when the wires are illuminated in this way.

The Clarks, in their micrometer of the great Washington telescope, have made the end of box T (fig. 15) transparent, and light is thrown on the webs from a lamp held by an assistant. Holden has very recently applied a lamp ingeniously hung so as to preserve its verticality and the constant direction of its light in a similar way, adding a plain silvered mirror inside the box and opposite the lamp, so as to illuminate the webs symmetrically. In the Clarks' and Holden's methods it is only the webs at right angles to the screw that are illuminated.

For illumination of the field, in very old telescopes, light was thrown on a small ivory reflector fixed outside the object-glass in the axis of the telescope by an arm fitting on the cell of the lens. This involved the aid of an assistant to direct lamplight on the ivory reflector, or the very frequent change of a lamp support. Afterwards the light from an attached lamp was introduced through a hole in the telescope-tube and thrown upon an elliptical plane (generally dull-gilt) having its centre part cut away sufficiently to avoid interruption of the cone of rays from the object-glass. Many ingenious modes of suspending the lamp have been invented for the purpose of securing a constant direction of its light coupled with verticality of the lamp. One of the best of these, due to Cooke, is shown in fig. 19. L is the lamp, P a prism to reflect

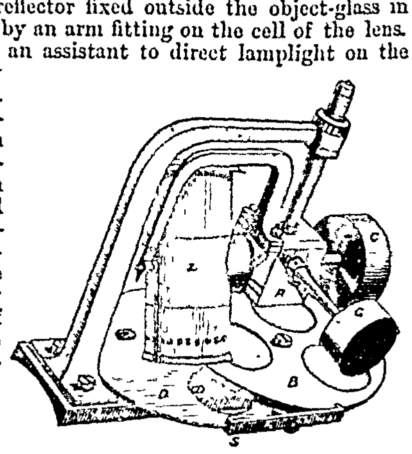

Fig. 19.

[1] It is asserted that webs from cocoons are more elastic, better shaped, and more durable than those obtained during an effort of the insect to escape. The best webs we have seen were from a cocoon obtained in Holland, but we have been unable to ascertain the name of the variety of spider.

[2] Argelander used to apply two drops of varnish at each end of his webs. He first fixed each extremity by a drop of shellac varnish, and after that had dried he applied a drop of copal varnish nearer the centre of the frame; the latter took a long time to harden, but gave ultimately a much stronger attachment.

its light into the tube, D a disk to regulate the quantity of light, B a disk with glasses to regulate the colour of the light, S a spring to clamp the disks, C the counterpoise of the lamp, G a poise to preserve the horizontality of the axis CL. But astronomers owe to the genius of Grubb the introduction of a more efficient and convenient system, viz., the performance of all necessary illumination of an astronomical telescope by a single lamp, and the perfect control of the illumination of the field or webs, and the regulation of these as to intensity or colour by simple motions from the eye-end. It is impossible to speak too highly of Grubb's efforts in this direction; he has broken the ground in this department of astronomical engineering, and rendered the working of so huge an instrument as the Vienna telescope of 27 inches aperture not only convenient, but easier for a single observer than that of a very small telescope of the older constructions.

But in the illumination of the field wires and scales of a micrometer Grubb's original method has recently been surpassed by one which is due to the Repsolds. We shall therefore describe the latter.

Fig. 20 represents the eye-end of a telescope. The reader will recognize the micrometer (figs. 16 and 17) previously described. L is a paraffin lamp fitting by a bayonet joint into a copper cover *c*. This effectually defends its glass chimney against accident, and protects the lamp from wind. The simple means by which this lamp is made to preserve its verticality in all positions of the telescope is evident from the figure. By this lamp alone the bright wire or bright field illumination is given at pleasure, and with any desired intensity, simply by movement of the small pin *p*.

The position circle and the head of the micrometer are also illuminated, as well as the declination circle, by the same lamp. AB is a cylindrical box, ending in a truncated cone towards A. It is shown, mid-section, in a plane passing through the telescope axis, in fig. 21, where all details unnecessary to the explanation of the illumination are omitted, and proportion of parts is sacrificed to clearness. P is a prism (fig. 21) that rotates with the lamp and reflects its light into AB. The flame of the lamp is in the focus of the lens *ll*, so that the rays become parallel after passing through it. There is a sliding motion to perfect this adjustment. There is a well-polished flat annular reflector of speculum metal *rr* (fig. 21), which reflects light upon the double mirror M (fig. 20), whence it is diverted to the two opposite points on the declination circle that are read by micrometer microscopes from the eye-end (the latter are omitted for sake of clearness).

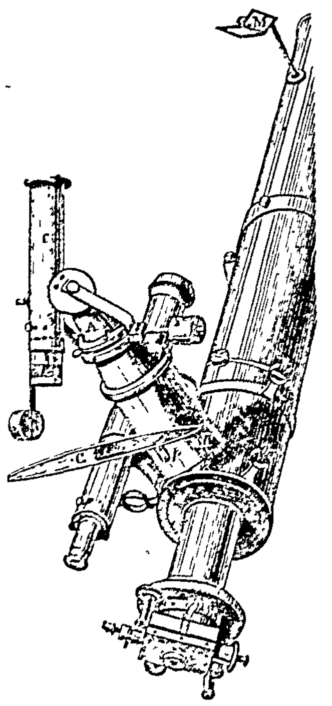

Fig. 20.

The little handle at p' and the dotted lines $p'z$ represent an iris-diaphragm, very ingeniously constructed, mounted on a plate of transparent glass. There is a flat ring of brass, carrying four pins, which is turned by the handle p', in a plane at right angles to P*n*. These pins work in spiral slots cut in four slides. Thus rotation of the ring causes the four slides to approach or recede from a centre. When the handle p' is in the middle of its range, the slides together form a disk as large as the hole in the diaphragm *dd*, and thus prevent all light from entering the telescope tube. When p' is pushed to one side of its range the slides move outwards leaving a square opening in the centre so that the light falls on the prism *n*,

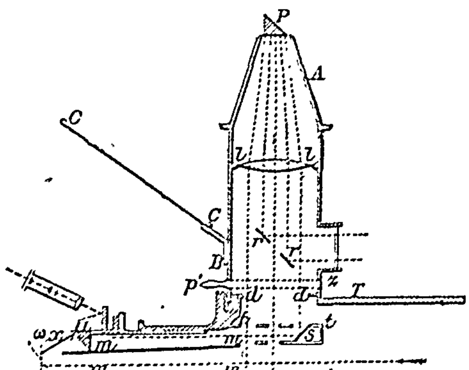

Fig. 21.

whence it is diverted to a silvered reflector cemented on the middle of the inner surface of the object-glass, and is then reflected back along the axis of the telescope to illuminate the field at ω. When p' is pushed to the other side of its range the slides approach and overlap at the centre, excluding light from *n* and allowing it to fall upon the reflector *s* instead. From *s* the light is thrown upon the webs ω, ω by reflexion from a white papier maché surface laid on the inside of a thin hollow brass truncated cone *xx*. The edge of this cone forms the circle seen within $\tau\tau$ in fig. 17. All stray light is prevented by the light-guard tube *mm*, which is attached to and moves with the rotating part of the micrometer. The result is to produce a symmetrical illumination of the whole system of webs in a perfectly dark field. It is also obvious that by placing p' at an intermediate position between the centre and the extremes of its range any desired modification of bright wire or bright field illumination can be obtained at pleasure.

The light falling on the papier maché hollow cone is intercepted at three points by prisms, one of which μ is shown in section. These prisms are inserted in the cylinder which carries the foundation plate of the micrometer box and rotate with it. Two of them divert light upon the reflectors (seen from different points of view in figs. 16, 17, 20). The third prism after two reflexions (figs. 16, 20) illuminates the micrometer head. The whole arrangement is in the highest degree elegant, and we have found it most simple and convenient in practice. The screen C (figs. 20 and 21)—made of thin copper and attached to AB—effectually protects the observer's eye from stray light from the lamp.

It has been found essential, in bright field illumination, when the highest accuracy is desired, to have the illuminating rays parallel with the telescope axis.

In the best telescopes of the future some plan like that of Repsold's, above described, will doubtless be adopted. It is probable also that with the introduction of condensers, in conjunction with the incandescent carbon light in vacuum, electricity will ultimately supersede the oil or paraffin lamp in illuminating astronomical instruments. A small "Swan lamp" can be placed anywhere, is unaffected by wind, and gives off comparatively little heat. These are most valuable qualities for the purpose in question.

The astronomer-royal (Mr Christie) has recently used luminous paint to render the measuring pointer of the Greenwich spectroscope visible at night. This paint, after exposure during the day to sunlight, shines at night with a dull phosphorescence sufficient to make the micrometer pointer, to which it is applied, faintly visible, and, it is stated, with very satisfactory results.

On the use of the filar micrometer consult Struve, *Mensuræ Micrometricæ*, St Petersburg, 1837; Brunnow, *Practical and Spherical Astronomy*; Chauvenel, *Practical and Spherical Astronomy*; Brunnow, *Astronomical Observations and Researches made at Dunsink*, Dublin, 1870, 1873, 1879; Ball, *ibid.*; Kaiser, *Leiden Observations*; and the papers of Dembowski in the *Astronomische Nachrichten*.

Double-Image Micrometers.

The discovery of the method of making measures by double images is stated to have been first suggested by Roemer about 1678. Roemer.
But no such suggestion occurs in the *Basis Astronomiæ* of Horrebow (Copenhagen, 1735), which contains the only works of Roemer that remain to us. It would appear that to Savary is due the first invention of a micrometer for measurement by double image. His heliometer (described in a paper communicated to the Royal Society in 1743, and printed, along with a letter from Short, in *Phil. Trans.*, 1753, p. 156) was constructed by cutting from a complete lens *abcd* the equal portions *aghc* and *acfe* (fig. 22). The segments *gbh* and *efd* so formed were then attached to the end of a tube having an internal diameter represented by the dotted circle (fig. 23). The width of each of the portions *aghc* and *acfe* cut away from the lens was made slightly greater than the focal length of lens × tangent of sun's greatest diameter. Thus at the focus two images of the sun were formed nearly in contact as in fig. 24. The small interval between the adjacent limbs was then measured with a wire micrometer.

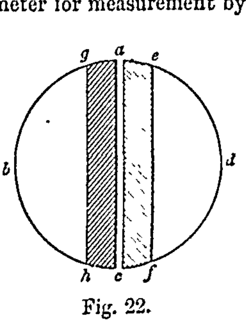

Fig. 22.

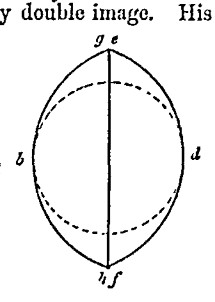

Fig. 23.

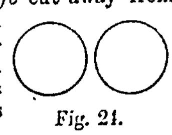

Fig. 24.

Savary also describes another form of heliometer, on the same Savary.
principle, in which the segments *aghc* and *acfe* are utilized by cementing their edges *gh* and *ef* together (fig. 25), and covering all except the portion indicated by the unshaded circle. Savary expresses preference for this second plan, and makes the pertinent remark that in both these models "the rays of red light in the two solar images will be next to each other, which will render the sun's disk more easy to be observed than the violet ones." This

he mentions "because the glasses in these two sorts are somewhat prismatical, but mostly those of the first model, which could therefore bear no great charge" (magnifying power).

A third model proposed by Savary consists of two complete lenses of equal focal length, mounted in cylinders side by side, and attached to a strong brass plate (fig. 26). Here, in order to fulfil the purposes of the previous models, the distance of the centres of the lenses from each other should only slightly exceed the tangent of sun's diameter × focal length of lenses. Savary dwells on the difficulty both of procuring lenses sufficiently equal in focus and of accurately adjusting and centring them.

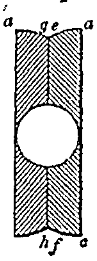

Fig. 25.

Bouguer. In the *Mém. Acad. de Paris*, 1748, Bouguer describes an instrument which he calls a heliometer. Lalande in his *Astronomie* (vol. ii. p. 639) mentions such a heliometer which had been in his possession from the year 1753, and of which he gives a representation on Plate XXVIII., fig. 186, of the same volume. Bouguer's heliometer was in fact similar to that of Savary's third model, with the important difference that, instead of both object-glasses being fixed, one of them is movable by a screw provided with a divided head. No auxiliary filar micrometer was required, as in Savary's heliometer, to measure the interval between the limbs of two adjacent images of the sun, it being only necessary to turn the screw with the divided head to change the distance between the object-glasses till the two images of the sun are in contact as in fig. 27. The differences of the readings of the screw, when converted into arc, afford the means of measuring the variations of the sun's apparent diameter.

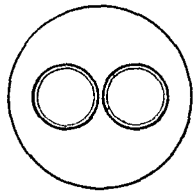
Fig. 26.

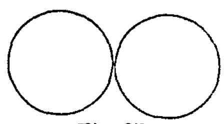
Fig. 27.

Dollond. On the 4th April 1754 Dollond communicated a paper to the Royal Society of London (*Phil. Trans.*, vol. xlviii. p. 551) in which he shows that a micrometer can be much more easily constructed by dividing a single object-glass through its axis than by the employment of two object-glasses. He points out—(1) that a telescope with an object-glass so divided still produces a single image of any object to which it may be directed, provided that the optical centres of the segments are in coincidence (*i.e.*, provided the segments retain the same relative positions to each other as before the glass was cut); (2) that if the segments are separated in any direction two images of the object viewed will be produced; (3) that the most convenient direction of separation for micrometric purposes is to slide these straight edges one along the other as the figure on the margin (fig. 28) represents them: "for thus they may be moved without suffering any false light to come in between them; and by this way of removing them the distance between their centres may be very conveniently measured, viz., by having a vernier's division fixed to the brass work that holds one segment, so as to slide along a scale on the plate to which the other part of the glass is fitted."

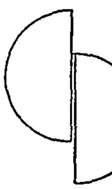
Fig. 28.

Dollond then points out three different types in which a glass so divided and mounted may be used as a micrometer:—

"1. It may be fixed at the end of a tube, of a suitable length to its focal distance, as an object-glass,—the other end of the tube having an eye-glass fitted as usual in astronomical telescopes.

"2. It may be applied to the end of a tube much shorter than its focal distance, by having another convex glass within the tube, to shorten the focal distance of that which is cut in two.

"3. It may be applied to the open end of a reflecting telescope, either of the Newtonian or the Cassegrain construction."

Dollond adds his opinion that the third type is "much the best and most convenient of the three"; yet it is the first type that has survived the test of time and experience, and which is in fact the modern heliometer

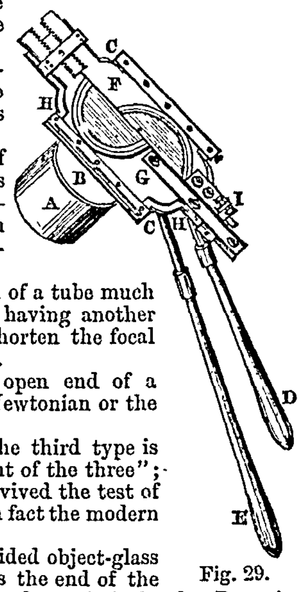

Fig. 29.

Fig. 29 illustrates Dollond's divided object-glass heliometer of the third type. A is the end of the reflecting telescope, upon which the adapter B is fitted. B carries a wheel (not seen in the figure) formed of a ring racked at the outer edge, and fixed to the brass plate CC, so that a pinion moved by the handle D may turn it into any position. Two plates F, G, with the attached semi-lenses, move in slides fixed to the plate CC,—simultaneous motion, in contrary directions, being communicated to them by turning the handle E, which drives a concealed pinion that works in the two racks seen in the highest part of the figure. The amount of separation of the semi-lenses is measured by a scale 5 inches long, subdivided to $\frac{1}{10}$th of an inch, and read by a vernier on the plate F to $\frac{1}{500}$th of an inch. In practical use this micrometer has never given satisfactory results (see Mosotti in the *Efemeride* of Milan for 1821). It must be remembered, however, that when Dollond gave preference to this type he had not invented the achromatic object-glass; his preference was fully justified under these circumstances. So far as we know no heliometer with a divided achromatic object-glass was ever made by the elder Dollond on the principle of his first type. His son, however, made what he called an object-glass micrometer, which was a great improvement on the elder Dollond's second type.

In the older construction the brass mountings of the semi-lenses obstructed the light entering the telescope in proportion to their separation, and the images were so coloured as to prevent the use of any but very low powers. In the later construction the movable segments are formed from a negative achromatic lens of much larger aperture than the object-glass of the telescope with which the micrometer is employed; and, for convenience in mounting, the segments *gbh* and *cdf* (fig. 22) are removed. In the fine example of this instrument at the Royal Observatory, Cape of Good Hope, the movable lenses consist of segments of the shape *gach* and *eacf* (fig. 22) cut from a complete negative achromatic combination of 8¼ inches aperture and about 41 feet focal length, composed of a double concave flint lens and a double convex crown. This is applied to an excellent achromatic telescope of 3½ inches aperture and 42 inches focal length. The instrument is represented in fig. 30; the same letters indicate the analogous parts of fig. 29. The frame CC, moved by teeth on its outer edge, carries one of the halves G of the lens, and a similar frame with teeth carries the other half F. A scale 8½ inches long is fastened like an edge-bar to the frame of the segment G, and each inch is subdivided into twenty parts, which are read off by a vernier to $\frac{1}{1000}$th of an inch, and, by estimation, this can easily be carried to $\frac{1}{2000}$th or $\frac{1}{3000}$th of an inch. The two movable frames are imbedded in a fixed plate HH, screwed to the adapter B, having a circular hole in its middle equal to the diameter of the object-glass. The slide of the segment G is moved by turning the milled head to the right of A, and the other segment F by means of a rack and pinion on the opposite side, the latter being turned from the eye-end by a handle not seen in the figure. A screw is provided for clamping the slide of the segment G, as it is intended that only the segment F shall be moved in making the final bisection. There is an index attached to the slide of G, reading on a rough scale engraved on the plate H, which is obviously intended for setting the optical centre of the segment G approximately as far from the optical axis of the telescope on one side as the optical centre of the segment F will be on the other side during the intended measurement. This arrangement not only permits the measurement of angles twice as great as would be possible if one segment were fixed, but is also important in increasing the symmetry of the measures. The vernier is placed at one end of the scale when the optical centres of the segments are in coincidence, and is provided with screws at I, which are intended for adjusting the zero of the scale. The younger Dollond has in this model retrograded, in some respects, from the admirable example of his father, who, as shown in fig. 29, not only gave the lenses automatic opposite motion symmetrically with respect to the axis of the telescope, but seems also to have provided for entire elimination of index error by making it possible to observe all angles on opposite sides of zero—a precaution possible in the later form only when very small angles are measured. Rotation of the micrometer in position angle is provided for as in the earlier form, but the instrument is not furnished with a position circle.

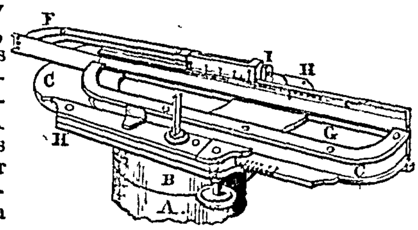

Fig. 30.

With one of these instruments of somewhat smaller dimensions (telescope 2½ inches aperture and 3½ feet focus) Triesnecker made a series of measurements at the observatory of Vienna which has been recently reduced by Dr Schur of Strasburg (*Nova Acta der Ksl. Leop.-Carol. Deutschen Akademie der Naturforscher*, xlv. No. 3). The angle between the stars ζ and *g* Ursæ maj. (708″·55) was measured on four nights; the probable error of a measure on one night was ± 0″·44. Jupiter was measured on eleven nights in the months of June and July 1794; from these measures Schur derives the values 35″·39 and 37″·94 for the polar and equatorial diameter respectively, at mean distance, corresponding with a compression 1/14·44. These agree satisfactorily with the corresponding values Triesnecker's measurements.

35″·21, 37″·60, 1/15·69 afterwards obtained by Bessel (*Konigsberger Beobachtungen*, xix. 102). From a series of measures of the angle between Jupiter's satellites and the planet, made in June and July 1794 and in August and September 1795, Schur finds the mass of Jupiter $= \frac{1}{1048 \cdot 55 \pm 1 \cdot 45}$, a result which accords perfectly with the received value of the mass derived from modern researches. The probable errors for the measures of one night are ±0″·577, ±0″·889, ±0″·542, ±1″·096, for Satellites I., II., III., and IV. respectively. It is probable that Triesnecker deduced the index error from his measures of the diameter of Jupiter, as, in 1794, the measures of diameter are made on the same nights with those of the measures of distance of the satellites, and it is possible that measures of diameter may have been made in 1795 but not published.

Considering the accuracy of these measures (an accuracy far surpassing that of any contemporary observations), it is somewhat surprising that this form of micrometer was never systematically used in any sustained or important astronomical researches, although a number of instruments of the kind were made by Dollond. Probably the last example of its employment is an observation of the transit of Mercury (November 4, 1868) by Mr Mann, at the Royal Observatory, Cape of Good Hope (*Monthly Notices R. A. S.*, vol. xxix. p. 197–209). The most important part, however, which this type of instrument seems to have played in the history of astronomy arises from the fact that one of them was in the possession of Bessel at Konigsberg during the time when his new observatory there was being built. In 1812 Bessel measured with it the angle between the components of the double star 61 Cygni and observed the great comet of 1811. He also observed the eclipse of the sun on May 4, 1818. In the discussion of these observations (*Konigsberger Beobacht.*, Abth. 5, p. iv) he found that the index error of the scale changed systematically in different position angles by quantities which were independent of the direction of gravity relative to the position angle under measurement, but which depended solely on the direction of the measured position angle relative to a fixed radius of the object-glass. Bessel attributed this to non-homogeneity in the object-glass, and determined with great care the necessary corrections. But he was so delighted with the general performance of the instrument, with the sharpness of the images, and the possibilities which a kindred construction offered for the measurement of considerable angles with micrometric accuracy, that he resolved, when he should have the choice of a new telescope for the observatory, to secure some form of heliometer.

Bessel's observations.

Nor is it difficult to imagine the probable course of reasoning which led Bessel to select the model of his new heliometer. Why, he might ask, should he not select the simple form of Dollond's first type? Given the achromatic object-glass, why should not it be divided? This construction would give all the advantage of the younger Dollond's object-glass micrometer and more than its sharpness of definition, without liability to the systematic errors which may be due to want of homogeneity of the object-glass; for the lenses will not be turned with respect to each other, but, in measurement, will always have the same relation in position angle to the line joining the objects under observation. It is true that the scale will require to be capable of being read with much greater accuracy than $\frac{1}{1000}$th of an inch—for that, even in a telescope of 10 feet focus, would correspond with 2″ of arc. But, after all, this is no practical difficulty,—for screws can be used to separate the lenses, and, by these screws, as in a Gascoigne micrometer, the separation of the lenses can be measured; or we can have scales for this purpose, read by microscopes, like the Troughton[1] circles of Piazzi or Pond, or those of the Carey circle, with almost any required accuracy.

Fraunhofer.

Whether Bessel communicated such a course of reasoning to Fraunhofer, or whether that great artist arrived independently at like conclusions, we have been unable to ascertain with certainty. The fact remains that before 1820[2] Fraunhofer had completed one or more of the five heliometers (3 inches aperture and 39 inches focus) which have since become historical instruments. In 1824 the great Konigsberg heliometer was commenced, and it was completed in 1829.

To sum up briefly the history of the heliometer. The first application of the divided object-glass and the employment of double images in astronomical measures is due to Savary in 1743. To Bouguer in 1748 is due the true conception of measurement by double image without the auxiliary aid of a filar micrometer, viz., by changing the distance between two object-glasses of equal focus. To Dollond in 1754 we owe the combination of Savary's idea of the divided object-glass with Bouguer's method of measurement, and the construction of the first really practical heliometers. To Fraunhofer, some time not long previous to 1820, is due, so far as we can ascertain, the construction of the first heliometer with an achromatic divided object-glass, *i.e.*, the first heliometer of the modern type.

Double-Image Micrometers with Divided Lenses.

Various micrometers have been invented besides the heliometer for measuring by double image. Ramsden's dioptric micrometer consists of a divided lens placed in the conjugate focus of the innermost lens of the erecting eye-tube of a terrestrial telescope. The inventor claimed that it would supersede the heliometer, but it has never done anything for astronomy. Dollond claims the independent invention and first construction of a similar instrument (Pearson's *Practical Astronomy*, vol. ii. p. 182). Of these and kindred instruments only two types have proved of practical value. Amici of Modena (*Mem. Soc. Ital.*, xvii. (1815) pp. 344–359) describes a micrometer in which a negative lens is introduced between the eye-piece and the object-glass. This lens is divided and mounted like a heliometer object-glass; the separation of the lenses produces the required double image, and is measured by a screw. Dawes has very successfully used this micrometer in conjunction with a filar micrometer, and finds that the precision of the measures is in this way greatly increased (*Monthly Notices*, vol. xviii. p. 58, and *Mem. R. A. S.*, vol. xxxv. p. 147).

In the improved form[3] of Airy's divided eye-glass micrometer (*Mem. R. A. S.*, vol. xv. pp. 199–209), the rays from the object glass pass successively through lenses as follows.

Lens	Distance from next Lens.	Focal Length.
a. An equiconvex lens	p	arbitrary $= p$
b. " "	2	3
c. Plano-convex, convex towards *b*	$1\frac{3}{4}$	1
d. Plano-convex, convex towards *c*	...	1

The lens *b* is divided, and one of the segments is moved by a micrometer screw. The magnifying power is varied by changing the lens *a* for another in which *p* has a different value. The magnifying power of the eye-piece is that of a single lens of focus $= \frac{1}{2}p$

In 1850 Valz pointed out that the other optical conditions could be equally satisfied if the divided lens were made concave instead of convex, with the advantage of giving a larger field of view (*Monthly Notices*, vol. x. p. 160).

The last improvement on this instrument is mentioned in the *Report* of the R. A. S. council, February 1865. It consists in the introduction by Simms of a fifth lens, but no satisfactory description has ever appeared. There is only one practical published[4] investigation of Airy's micrometer that is worthy of mention, viz., that of Kaiser (*Annalen der Sternwarte in Leiden*, iii. pp. 111–274). The reader is referred to that paper for an exhaustive history and discussion of the instrument.[5] It is somewhat surprising that, after Kaiser's investigations, observers should continue, as many have done, to discuss their observations with this instrument as if the screw-value were constant for all angles.

Steinheil's ocular micrometer.

Steinheil (*Journal Savant de Munich*, 28th February 1843) describes a "heliomètre-oculaire" which he made for the great Pulkowa refractor, the result of consultations between himself and the elder Struve. It is essentially the same in principle as Amici's micrometer, except that the divided lens is an achromatic positive instead of a negative lens. Struve (*Description de l'Observatoire Central de Pulkowa*, pp. 196, 197) adds a few remarks to Steinheil's description, in which he states that the images have not all desirable precision,—a fault perhaps inevitable in all micrometers with divided lenses, and which is probably in this case aggravated by the fact that the rays falling upon the divided lens have considerable convergence. He, however, successfully employed the instrument in measuring double stars, so close as 1″ or 2″, and using a power of 300 diameters, with results that agreed satisfactorily amongst themselves and with those obtained with the filar micrometer. If Struve had employed a properly proportioned double

[1] The circles by Reichenbach, then almost exclusively used in Germany, were read by verniers only.

[2] The diameter of Venus was measured with one of these heliometers at the observatory of Breslau by Brandes in 1820 (*Berlin Jahrbuch*, 1824, p. 164)

circular diaphragm, fixed symmetrically with the axis of the telescope in front of the divided lens and turning with the micrometer, it is probable that his report on the instrument would have been still more favourable. This particular instrument has historical interest, having led Struve to some of those criticisms of the Pulkowa heliometer which ultimately bore such valuable fruit (see below).

Ramsden (*Phil. Trans.*, vol. xix. p. 419) has suggested the division of the small speculum of a Cassegrain telescope and the production of double image by micrometric rotation of the semi-specula in the plane passing through their axis. Brewster (*Ency. Brit.*, 8th ed., vol. xiv. p. 749) proposes a plan on a like principle, by dividing the plane mirror of a Newtonian telescope. Again, in an ocular heliometer by Steinheil double image is similarly produced by a divided prism of total reflexion placed in parallel rays. But practically these last three methods are failures. In the last the field is full of false light, and it is not possible to give sufficiently minute and steady separation to the images; and there are of necessity a collimator, two prisms of total reflexion, and a small telescope through which the rays must pass; consequently there is great loss of light.

Micrometers Depending on Double Refraction.

Rochon's micrometer. To the Abbé Rochon (*Jour. de Phys.*, liii., 1801, pp. 169–198) is due the happy idea of applying the two images formed by double refraction to the construction of a micrometer. He fell upon a most ingenious plan of doubling the amount of double refraction of a prism by using two prisms of rock-crystal, so cut out of the solid as to give each the same quantity of double refraction, and yet to double the quantity in the effect produced. The combination so formed is known as Rochon's prism. Such a prism he placed between the object-glass and eye-piece of a telescope. The separation of the images increases as the prism is approached to the object-glass, and diminishes as it is approached towards the eye-piece.

Arago (*Comptes Rendus*, xxiv., 1847, pp. 400–402) found that in Rochon's micrometer, when the prism was approached close to the eye-piece for the measurement of very small angles, the smallest imperfections in the crystal or its surfaces were inconveniently magnified. He therefore selected for any particular measurement such a Rochon prism as when fixed between the eye and the eye-piece (*i.e.*, where a sunshade is usually placed) would, combined with the normal eye-piece employed, bring the images about to be measured nearly in contact. He then altered the magnifying power by sliding the field lens of the eye-piece (which was fitted with a slipping tube for the purpose) along the eye-tube, till the images were brought into contact. By a scale attached to the sliding tube the magnifying power of the eye-piece was deduced, and this combined with the angle of the prism employed gave the angle measured. If p'' is the refracting angle of the prism, and n the magnifying power of the eye-piece, then p''/n will be the distance observed. Arago made many measures of the diameters of the planets with such a micrometer.

Dollond (*Phil. Trans.*, 1821, pp. 101–103) describes a double-image micrometer of his own invention in which a sphere of rock-crystal is substituted for the eye-lens of an ordinary eye-piece. In this instrument (figs. 31, 32) a is the sphere, placed in half-holes on

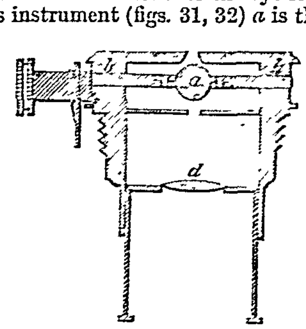

Fig. 31.

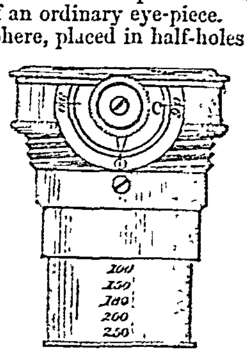

Fig. 32.

the axis bb, so that when its principal axis is parallel to the axis of the telescope it gives only one image of the object. In a direction perpendicular to that axis it must be so placed that when it is moved by rotation of the axis bb the separation of the images shall be parallel to that motion. The angle of rotation is measured on the graduated circle C. The angle between the objects measured is $= r \sin 2\theta$, where r is a constant to be determined for each magnifying power employed,[1] and θ the angle through which the sphere has been turned from zero (*i.e.*, from coincidence of its principal axis with that of the telescope). The maximum separation is consequently at 45° from zero. The measures can be made on both sides of zero for eliminating index error. There are considerable difficulties of construction, but these have been successfully overcome by Dollond; and in the hands of Dawes (*Mem. R. A. S.*, xxxv. p. 144 *sq.*) such instruments have done valuable service. They are liable to the objection that their employment is limited to the measurement of very small angles, viz., 13″ or 14″ when the magnifying power is 100, and varying inversely as the power. Yet the beautiful images which these micrometers give permit the measurement of very difficult objects as a check on measures with the parallel-wire micrometer.

[1] Dollond provides for changing the power by sliding the lens d nearer or farther from a.

The Modern Heliometer.

Königsberg heliometer. The Königsberg heliometer is represented in fig. 33. No part of the equatorial mounting is shown in the figure, as it resembles in every respect the usual Fraunhofer mounting. An adapter h is fixed on a telescope-tube, made of wood, in Fraunhofer's usual fashion. To this adapter is attached a flat circular flange h. The slides carrying the segments of the divided object-glass are mounted on a

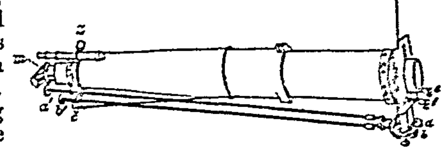

Fig. 33.

plate, which is fitted and ground to rotate smoothly on the flange h. Rotation is communicated by a pinion, turned by the handle c (concealed in the figure), which works in teeth cut on the edge of the flange h. The counterpoise w balances the head about its axis of rotation. The slides are moved by the screws a and b, the divided heads of which serve to measure the separation of the segments. These screws are turned from the eye-end by bevelled wheels and pinions, the latter connected with the handles a', b'. The reading micrometers e, f also serve to measure, independently, the separation of the segments, by scales attached to the slides; such measurements can be employed as a check on those made by the screws. The measurement of position angles is provided for by a graduated circle attached to the head. There is also a position circle, attached at m to the eye-end, provided with a slide to move the eye-piece radially from the axis of the telescope, and with a micrometer to measure the distance of an object from that axis. The ring which carries the supports of the handles a', b', c is capable of a certain amount of rotation on the tube. The weight of the handles and their supports is balanced by the counterpoise z. This ring is necessary in order to allow the rods to follow the micrometer heads when the position angle is changed. Complete rotation of the head is obviously impossible because of the interference of the declination axis with the rods, and therefore, in some angles, objects cannot be measured in two positions of the circle. The object-glass has an aperture of 6½ inches, and 102 inches focal length.

There are three methods in which this heliometer can be used.

First Method.—One of the segments is fixed in the axis of the telescope, and the eye-piece is also placed in the axis. Measures are made with the moving segment displaced alternately on opposite sides of the fixed segment.

Second Method.—One segment is fixed, and the measures are made as in the first method, excepting that the eye-piece is placed symmetrically with respect to the images under measurement. For this purpose the position angle of the eye-piece micrometer is set to that of the head, and the eye-piece is displaced from the axis of the tube (in the direction of the movable segment) by an amount equal to half the angle under measurement.

Third Method.—The eye-piece is fixed in the axis, and the segments are symmetrically displaced from the axis each by an amount equal to half the angle measured.

Of these methods Bessel generally employed the first because of its simplicity, notwithstanding that it involved a resetting of the right ascension and declination of the axis of the tube with each reversal of the segments. The chief objections to the method are that, as one star is in the axis of the telescope and the other displaced from it, the images are not both in focus of the eye-piece,[2] and the rays from the two stars do not make the same angle with the optical axis of each segment. Thus the two images under measurement are not defined with equal sharpness and symmetry. The second method is free from the objection of non-coincidence in focus of the images, but is more troublesome in practice from the necessity for frequent readjustment of the position of the eye-piece. The third method is the most symmetrical of all, both in observation and reduction; but it was not employed by Bessel, on the ground that it involved the determination of the errors of two screws instead of one. On the other hand it is not necessary to reset the telescope after each reversal of the segments.[3]

[2] The distances of the optical centres of the segments from the eye-piece are in this method as 1 : secant of the angle under measurement. In Bessel's heliometer this would amount to a difference of $\frac{15}{1000}$th of an inch when an angle of 1° is measured. For two degrees the difference would amount to nearly $\frac{1}{16}$th of an inch. Bessel confined his measures to distances considerably less than 1°.

[3] In criticizing Bessel's choice of methods, and considering the loss of time involved in each, it must be remembered that Fraunhofer provided no means of

When Bessel ordered the Königsberg heliometer, he was anxious to have the segments made to move in cylindrical slides, of which the radius should be equal to the focal length of the object-glass. Fraunhofer, however, did not execute this wish, on the ground that the mechanical difficulties were too great.

Wichmann states (*Königsb. Beobach.*, xxx. p. 4) that Bessel had indicated, by notes in his handbooks, the following points which should be kept in mind in the construction of future heliometers:—(1) The segments should move in cylindrical slides;[1] (2) the screw should be protected from dust;[2] (3) the zero of the position circle should not be so liable to change;[3] (4) the distance of the optical centres of the segments should not change in different position angles or otherwise;[4] (5) the points of the micrometer screws should rest on ivory plates;[5] (6) there should be an apparatus for changing the screen.[6]

The elder Struve, in describing the Pulkowa heliometer,[7] made by Merz in 1839 on the model of Bessel's heliometer, submits the following suggestions for its improvement:[8]—(1) to give automatically to the two segments simultaneous equal and opposite movement;[9] and (2) to make the tube of brass instead of wood; to attach the heliometer head firmly to this tube; to place the eye-piece permanently in the axis of the telescope; and to fix a strong cradle on the end of the declination axis, in which the tube, with the attached head and eye-piece, could rotate on its axis.

Both suggestions are important. The first is originally the idea of Dollond (fig. 29); its advantages were overlooked by his son (description of fig. 30), and it seems to have been quite forgotten till resuggested by Struve. But the method is not available if the separation is to be measured by screws; it is found, in that case, that the direction of the final motion of turning of the screw must always be such as to produce motion of the segment against gravity, otherwise the "loss of time" is apt to be variable. Thus the simple connexion of the two screws by cog-wheels to give them automatic opposite motion is not an available method unless the separation of the segments is independently measured by scales.

Struve's second suggestion has been adopted in nearly all succeeding heliometers. It permits complete rotation of the tube and measurement of all angles in reversed positions of the circle; the handles that move the slides can be brought down to the eye-end, inside the tube, and consequently made to rotate with it; and the position circle may be placed at the end of the cradle next the eye-end where it is convenient of access. Struve also points out that by attaching a fine scale to the focussing slide of the eye-piece, and knowing the coefficient of expansion of the brass tube, the means would be provided for determining the absolute change of the focal length of the object-glass at any time by the simple process of focussing on a double star. This, with a knowledge of the temperature of the screw or scale and its coefficient of expansion, would enable the change of screw value to be determined at any instant. Or, if we suppose the temperature of the instrument to be the same in all its parts, the changed scale value becomes simply a function of the reading of the focal scale.

Bonn heliometer.

It is probable that the Bonn heliometer was in course of construction before these suggestions of Struve were published or discussed, since its construction resembles that of the Königsberg and Pulkowa instruments. Its dimensions are similar to those of the former instrument. Bessel, having been consulted by the celebrated statesman Sir Robert Peel, on behalf of the Radcliffe trustees, as to what instrument, added to the Radcliffe Observatory, would probably most promote the advancement of astronomy, strongly advised the selection of a heliometer. The order for the instrument was given to the Repsolds in 1840, but "various circumstances, for which the makers are not responsible, contributed to delay the completion of the instrument, which was not delivered before the winter of 1848."[10] The building to receive it was commenced in March 1849 and completed in the end of the same year. This splendid instrument has a superb object-glass of $7\frac{1}{2}$ inches aperture and 126 inches focal length. The makers availed themselves of Bessel's suggestion to make the segments move in cylindrical slides, and of Struve's to have the head attached to a brass tube; the eye-piece is set permanently in the axis, and the whole rotates in a cradle attached to the declination axis. They provided a splendid, rigidly mounted, equatorial stand, fitted with every luxury in the way of slow motion, and scales for measuring the displacement of the segments were read by powerful micrometers from the eye-end.[11] It is somewhat curious that, though Struve's second suggestion was adopted, his first was overlooked by the makers. But it is still more curious that it was not afterwards carried out, for the communication of automatic symmetrical motion to both segments only involves a simple alteration previously described. But, as it came from the hands of the makers in 1849, the Oxford heliometer was incomparably the most powerful and perfect instrument in the world for the highest order of micrometric research. It so remained, unrivalled in every respect, till 1873; it remains still, optically, the most powerful heliometer in the world; and, with a few alterations, it might almost rival the most recent instruments in practical convenience and accuracy. These alterations, all of which could be made without great difficulty, are the following:—

(*a*) Beyond the automatic symmetrical motion above-described, the instrument should be fitted with means for adjusting the screens from the eye-end (see footnote [6] in last column).

(*b*) The arrangement of the scales should be changed. At present both scales are read separately by separate micrometers, each relative to a separate fiducial line. What the observer requires is the difference of the readings of the two scales, and this can obviously be most quickly and accurately obtained if the edges of the two scales are brought together, and both are read, relatively to each other, by the same micrometer.

(*c*) The unsatisfactory motion in position angle should be replaced by the action of a pinion (attached to the cradle) in the teeth of a wheel (attached to the tube).[12]

(*d*) The position circle should be read by telescopes or microscopes attached to the cradle, and accessible from the eye-end.

(*e*) It would add greatly to the rapidity of work and the ease of the observer if a small declination circle were attached to the cross-head, capable of being read from the eye-end.

As the transit of Venus of 1874 approached, preparations were set on foot by the German Government in good time; a commission of the most celebrated astronomers was appointed, and it was resolved that the heliometer should be the instrument chiefly relied on. The four long-neglected small heliometers made by Fraunhofer were brought into requisition. Fundamental alterations were made upon them:—their wooden tubes were replaced by tubes of metal; means of measuring the focal point were provided; symmetrical motion was given to the slides; scales on each slide were provided instead of screws for measuring the separation of the segments, and both scales were read by the same micrometer microscope; a metallic thermometer was added to determine the temperature of the scales. These small instruments have since done admirable work in the hands of Schur, Hartwig, Kustner, and Elkin.

Russian heliometers.

The Russian Government ordered three new heliometers (each of 4 inches aperture and 5 feet focal length) from the Repsolds, and the design for their construction was superintended by Struve, Auwers,

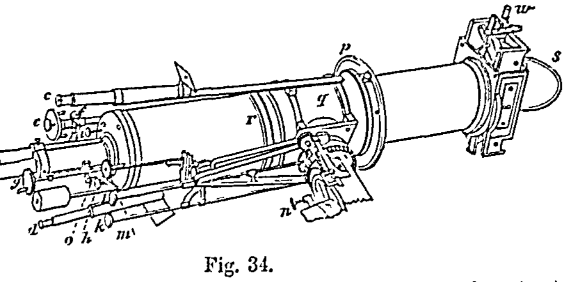

Fig. 34.

and Winnecke, the last-named making the necessary experiments at Carlsruhe. Fig. 34 represents the type of instrument which re-

reading the screws or even the heads from the eye-end. Bessel's practice was to unclamp in declination, lower and read off the head, and then restore the telescope to its former declination reading, the clockwork meanwhile following the stars in right ascension. The setting of both lenses symmetrically would, under such circumstances, be very tedious.

1 This most important improvement would permit any two stars under measurement each to be viewed in the optical axis of each segment. The optical centres of the segments would also remain at the same distance from the eye-piece at all angles of separation. Thus, in measuring the largest as well as the smallest angles, the images of both stars would be equally symmetrical and equally well in focus. Modern heliometers made with cylindrical slides measure angles over two degrees, the images remaining as sharp and perfect as when the smallest angles are measured.

2 Bessel found, in course of time, that the original corrections for the errors of his screw were no longer applicable. He considered that the changes were due to wear, which would be much lessened if the screws were protected from dust.

3 The tube, being of wood, was probably liable to warp and twist in a very uncertain way.

4 We have been unable to find any published drawing showing how the segments are fitted in their cells.

5 We have been unable to ascertain the reasons which led Bessel to choose *ivory* planes for the end-bearings of his screws. He actually introduced them in the Königsberg heliometer in 1810, and they were renewed in 1848 and 1850.

6 A screen of wire gauze, placed in front of the segment through which the fainter star is viewed, was employed by Bessel to equalize the brilliancy of the images under observation. An arrangement, afterwards described, has been fitted in modern heliometers for placing the screen in front of either segment by a handle at the eye-end.

7 This heliometer resembles Bessel's, except that its foot is a solid block of granite instead of the ill-conceived wooden structure that supported his instrument. The object-glass is of 7·4 inches aperture and 123 inches focus.

8 *Description de l'Observatoire central de Pulkowa*, p. 208.

9 Steinheil applied such motion to a double-image micrometer made for Struve. This instrument suggested to Struve the above-mentioned idea of employing a similar motion for the heliometer.

10 Manuel Johnson, M.A., Radcliffe observer, *Astronomical Observations made at the Radcliffe Observatory, Oxford, in the year* 1850, Introduction, p. iii.

11 The illumination of these scales is interesting as being the first application of electricity to the illumination of astronomical instruments. Thin platinum wire was rendered incandescent by a voltaic current; a small Swan light and condenser would probably now be found more satisfactory.

12 This has been recently carried out by Stone, the present Radcliffe observer, on Gill's suggestion.

sulted from their labours. The brass tube, strengthened at the bearing points by strong truly-turned collars, rotates in the cast-iron cradle q attached to the declination axis. a is the eye-piece fixed in that axis, b the micrometer for reading both scales.

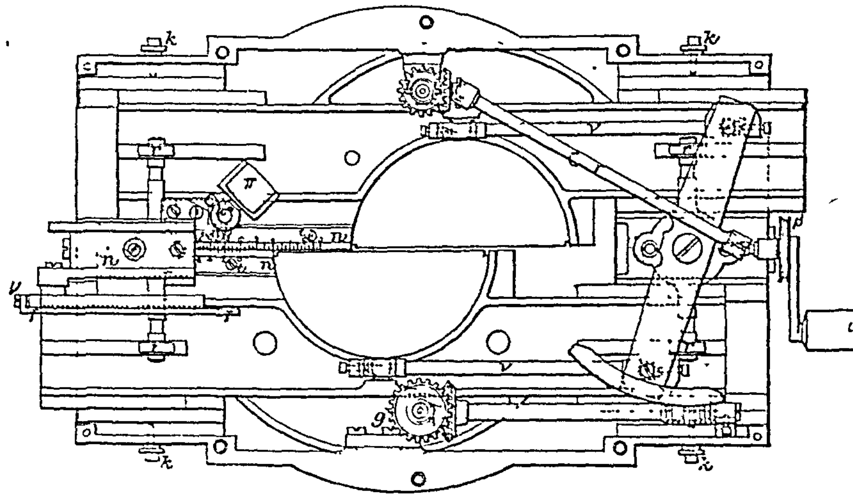

Fig. 35.

c, d are telescopes for reading the position circle p, e the handle for quick motion in position angle, f the slow motion in position angle, g the handle for changing the separation of the segments by acting on the bevel-wheel g' (fig. 35). h is a milled head connected by a rod with h' (fig. 35), for the purpose of interposing at pleasure the prism π in the axis of the reading micrometer; this enables the observer to view the graduations on the face of the metallic thermometer $\tau\tau$ (composed of a rod of brass and a rod of zinc). i is a milled head connected with the wheel $i'i'$ (fig. 35), and affords the means of placing the screen s (fig. 34), counterpoised by w over either half of the object-glass. k clamps the telescope in declination, n clamps it in right ascension, and the handles m and l provide slow motion in declination and right ascension respectively

The details of the interior mechanism of the "head" will be almost evident from fig. 35 without description. The screw, turned by the wheels at g', acts in a toothed arc, whence, as shown in the figure, equal and opposite motion is communicated to the slides by the jointed rods v, v. The slides are kept firmly down to their bearings by the rollers r, r, r, r, attached to axes which are, in the middle, very strong springs. Side-shake is prevented by the screws and pieces k, k, k, k. The scales are at n, n; they are fastened only at the middle, and are kept down by the brass pieces t, t.

Lord Lindsay's heliometer. A similar heliometer was made by the Repsolds to the order of Lord Lindsay for his Mauritius expedition in 1874. It differed only from the three Russian instruments in having a mounting by the Cookes in which the declination circle reads from the eye-end.[1] This instrument was afterwards most generously lent by Lord Lindsay to Gill for his expedition to Ascension in 1877.[2]

These four Repsold heliometers proved to be excellent instruments, easy and convenient in use, and yielding results of very high accuracy in measuring distances. Their slow motion in position angle, however, was not all that could be desired. When small movements were communicated to the handle e (fig. 34) by the tangent screw f, acting on a small toothed wheel clamped to the rod connected with the driving pinion, there was apt to be a torsion of the rod rather than an immediate action. Thus the slow motion would take place by jerks instead of with the necessary smoothness and certainty. When the heliometer part of Lord Lindsay's heliometer was acquired by Gill in 1879, he changed the manner of imparting the motion in question. A square toothed racked wheel was applied to the tube at r (fig. 34). This wheel is acted on by a tangent screw whose bearings are attached to the cradle; the screw is turned by means of a handle supported by bearings attached to the cradle, and coming within convenient reach of the observer's hand. The tube turns smoothly in the racked wheel, or can be clamped to it at the will of the observer. This alteration and the new equatorial mounting have been admirably made by Grubb; the result is completely successful. The instrument so altered has been in constant use at the Cape Observatory since March 1881 in determining the parallax of the more interesting southern stars.

Yale College heliometer. Still more recently the Repsolds have completed a new heliometer for Yale College, New Haven, United States. The object-glass is of 6 inches aperture and 98 inches focal length. The mounting, the tube, objective-cell, slides, &c., are all of steel.[3] The instrument is shown in fig. 36. The circles for position angle and declination are read by micrometer microscopes illuminated by the lamp L; the scales are illuminated by the lamp l. T is part of the tube proper, and turns with the head. The tube V, on the contrary, is attached to the cradle, and merely forms a support for the finder Q, the handles at f and p, and the moving ring P. The latter gives quick motion in position angle; the handles at p clamp and give slow motion in position angle, those at f clamp and give slow motion in right ascension and declination. a is the eye-piece, b the handle for moving the segments, c the micrometer microscope for reading the scales and scale micrometer, d the micrometer readers of the position and declination circles, e the handle for rotating the large wheel E which carries the screens. The hour circle is also read by microscopes, and the instrument can be used in both positions (tube preceding and

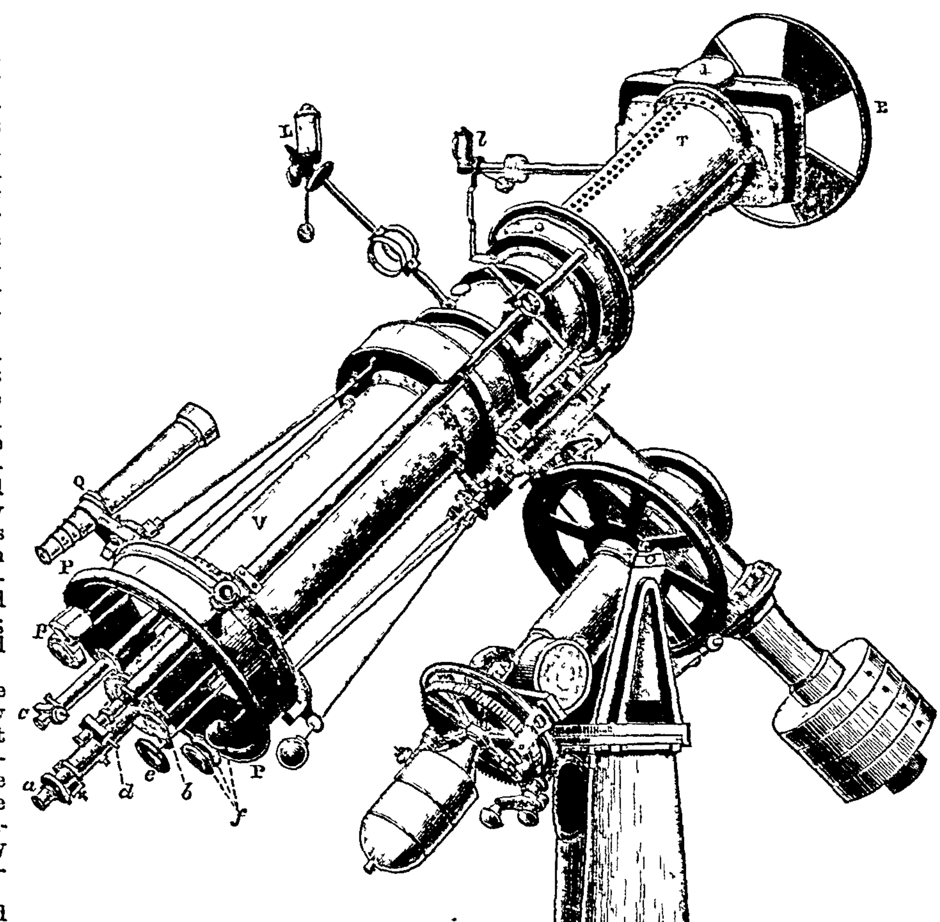

Fig. 36.

[1] For a detailed description of this instrument see *Dunecht Publications*, vol. ii.

[2] *Mem. Royal Astronomical Society*, vol. xlvi pp. 1-172.

[3] The primary object was to have the object-glass mounted in steel cells, which more nearly correspond in expansion with glass. It became then desirable to make the head of steel for sake of uniformity of material, and the advantages of steel in lightness and rigidity for the tube then became evident.

following) for the elimination of the effect of flexure on the position angles.

There is very little left to criticize in this instrument. It embraces the results of all knowledge and experience on the subject to the present time. In one point, however, modern heliometers have a disadvantage compared with the older forms. A great advance in accuracy was, no doubt, made when the screw was abandoned as a means both of moving and measuring the displacement of the slides.[1] But it is obviously much quicker to read and record the indication of one screw-head than to bisect two or four scale-divisions and enter the corresponding readings. Auwers, in his researches on the parallax of 61 Cygni,[2] was able, with the Königsberg heliometer, to make forty pointings in about an hour; it is quick work to make sixteen pointings (reading two divisions on each scale at each pointing) with the modern heliometer in the same time, when attention is paid to the desirable reversals of the segments and of the position circle and the resettings in right ascension and declination. Now time during opportunities of good definition (or otherwise)[3] is too precious to be sacrificed, if it can be saved even by ten-fold labour afterwards. Carrington[4] has suggested the possible use of photography to record the readings of astronomical circles, and since his day "Swan lights" and "sensitive dry plates" seems to have brought his suggestion within the range of practice. A special microscope, fitted with an aplanatic photographic objective and a well-contrived carrier, might be made automatically to expose a different part of a narrow dry plate, by mere pressure or turning of a button after each bisection. Each plate might easily record the sixteen bisections which constitute a complete measure of two pairs of stars (as in a parallax determination). As it is only necessary to photograph two divisions of each scale, the photographic enlargement of these divisions need only be limited by the sensitiveness of the plates and the power of the illumination to produce a picture in a conveniently short space of time. The plates employed at night could be conveniently developed the following day and measured with a special apparatus at any convenient time and with almost any desired accuracy. Were such a system reduced to practice it would at least double, perhaps treble, an observer's possible output of work.

Reversing prism.

Gill has introduced a powerful auxiliary to the accuracy of heliometer measures in the shape of a reversing prism placed in front of the eye-piece, between the latter and the observer's eye. If measures are made by placing the image of a star in the centre of the disk of a planet, the observer may have a tendency to do so systematically in error from some acquired habit or from natural astigmatism of the eye. But by rotating the prism 90° the image is presented entirely reversed to the eye, so that in the mean of measures made in two such positions personal error is eliminated. Similarly the prism may be used for the study and elimination of personal errors depending on the angle made by a double star with the vertical. The best plan of mounting such a prism has been found to be the following. l', l^2 (fig. 37) are the eye lens and field lens respectively of a Merz positive eye-piece. In this construction the lenses are much closer together and the diaphragm for the eye is much farther from the lenses than in Ramsden's eye-piece. The prism p is fitted accurately into brass slides (care has to be taken in the construction to place the prism so that an object in the centre of the field will so remain when the eye-piece is rotated in its adapter). There is a collar, clamped by the screw at S, which is so adjusted that the eye-piece is in focus when pushed home, in its adapter, to this collar. The prism and eye-piece are then rotated together in the adapter.

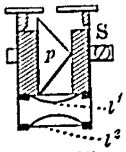

Fig. 37.

On the theory of the heliometer and its use consult Bessel, *Astronomische Untersuchungen*, vol. i.; Hansen, *Ausführliche Methode mit dem Fraunhoferschen Heliometer anzustellen*, Gotha, 1827; Chauvenet, *Spherical and Practical Astronomy*, vol. ii. pp. 403–436, Philadelphia and London, 1876; Seeliger, *Theorie des Heliometers*, Leipsic, 1877; Lindsay and Gill, *Dunecht Publications*, vol. ii., Dunecht (for private circulation), 1877; Gill, *Memoirs of the Royal Astronomical Society*, vol. xlvi. pp. 1–172.

Micrometers which Involve the Employment of the Diurnal Motion.

Advantage is often taken of the diurnal motion to measure the relative positions of stars. The varieties of reticules and scales that have been employed are far too numerous even for mention in detail. The following are the means and methods by which most work has been done, and they are typical of all the others. In the focus of his meridian telescope Lacaille had a brass diaphragm in which was cut a hole, having parallel, sharp, straight edges of the shape shown in fig. 38. The longer diagonal of the rhomboid so formed was at right angles, and the shorter parallel, to the diurnal motion. The method of observation consisted in noting the instant of ingress and egress of each star which presented itself. The mean of the times thus noted for each star gave the time of its transit over the imaginary line ab, whilst the difference between the instant of ingress and that of egress (converted into arc by the known approximate declination) gave the length of the chord traversed by the star parallel to the imaginary line cd. Hence (the dimensions of the rhomboid being known) the difference of the star's declination from the line cd became known (the observer was of course careful to note whether the star passed to north or south of cd). Thus every star that crossed the field was observed, all their right ascensions were referred to the clock-time of passing ab, and all their declinations to that of cd; hence their mutual differences of right ascension and declination were known. In this way, in the short space of ten months, Lacaille observed nearly ten thousand stars at the Cape of Good Hope in the years 1751–52.[5] — Lacaille's rhomboid.

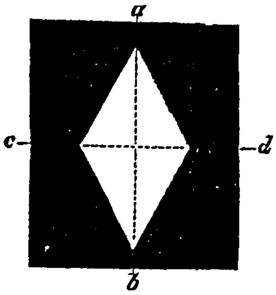

Fig. 38.

Ring micrometer. Fraunhofer's ring micrometer consists of a ring of steel, very truly turned, mounted in a hole cut in a circular disk of glass. The ring is placed in the focus of a telescope, and viewed by a positive eye-piece. The observer notes the instants when the two objects enter and emerge from each side of the ring. The only data required for computing the difference of right ascension and declination of the two objects are the times above mentioned, the diameter of the ring, and *the approximate declination of one of the objects*. The latter is always known. The methods of determining the former and of reducing the observations are to be found in every work on practical astronomy. The ring micrometer has been largely used in observing comets.

Argelander's scale. Argelander, in making his famous survey of the northern heavens,[6] employed a semicircle of glass, the straight edge of which (truly ground) crosses the centre of the field of view at right angles to the diurnal motion of the stars. Differences of right ascension were directly observed at this edge, whilst differences of declination were noted by strong dark lines drawn at right angles to the edge at each 10′ of arc. A telescope of 3 inches aperture with a magnifying power of 10 diameters commanded a field of 3° 20′ in declination. One observer was placed at the telescope, another at the clock. The telescope observer marked the instant when the star touched the glass edge, by calling sharply the word "eight" or "nine," &c., which also indicated the magnitude; the same observer also noted and recorded the reading of the declination scale (where the star crossed it), without removing his eye from the telescope. The clock observer wrote down the magnitude called out by the telescope observer, and the instant by the clock when the word was given. The two records were then compared after the observations of the night were over. In this way Schönfeld and Krueger (Argelander's assistants) observed and catalogued about three hundred thousand stars. The probable error of an observation is about ±0·7 sec. in right ascension and ±0′·4 in declination.

Bond's mica declinometer. Bond[7] employed a very similar arrangement, differing only from Argelander's in having the scale cut on a sheet of transparent mica $\frac{1}{1000}$th of an inch in thickness. Very oblique illumination was employed, and the divisions and figures were seen bright upon a dark background. The range of declination was limited to 10′, the scale was divided to 10″, the right ascensions were observed by chronographic registration, and the great refractor of the Cambridge U. S. Observatory (with an aperture of 15 inches and power of 140) was employed. The probable errors in right ascension and declination were found to be ±0·06 sec. in right ascension and ±0″·6 in declination—results of marvellous accuracy considering the amount of work accomplished in a short time and the faintness (eleven to twelve magnitudes) of the stars observed.

Peters's zones. We were on the point of criticizing Bond's programme as somewhat too ambitious for realization without cooperation (it would take about twenty-six thousand hours of observing to carry out the scheme for the northern hemisphere alone) when we received from Peters of Clinton, U. S., the first twenty maps of a series which will include the whole of the sky between declination +30° and −30°. If we consider that all the stars in these maps of the eleventh magnitude or brighter have been observed by a method similar to Bond's, that the enormous additional labour of frequent revision has been undertaken, and all stars visible with a power of 80 in a telescope of 13 inches aperture (about fourteenth magnitude) have been filled in

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1 Screws, as Auwers's discussion of Bessel's observations ("Parallaxe von 61 Cygni," *Abhandlungen der Konigl. Akad. der Wissenschaften zu Berlin*, 1868) has shown, are apt to wear and change their errors. It is, besides, undesirable to apply force and friction to a delicate standard of measure.

2 *Astron. Nachrichten*, No. 1416.

3 For example, in determining the diurnal parallax of a planet the most favourable conditions are limited on the one hand by the uncertainties of refraction at large zenith distances, and on the other by the small parallax factors of small zenith distances. It would probably be best to secure all the observations between 50° and 60° ZD, and this would only be possible with special facilities for reading the scales.

4 *Monthly Notices R. A. S.*, vol. xxx. p. 46.

5 Lacaille, *Cœlum Australe Stelliferum*, Paris, 1763, and *A Catalogue of 9766 Stars, from the Observations of Lacaille*, London, 1847.

6 *Atlas des Nordlichen Gestirnten Himmels*, Bonn, 1863, Introduction.

7 *Annals of the Astronomical Observatory, Harvard College*, vol. i. part ii.

by alignment, *and that all this results from the unaided labour of a single observer*, we find that our ideas of *the possible* have to be modified, when such a man undertakes a work with persistent unity of purpose for more than twenty years (1860–83).

Berlin declinograph. There is an ingenious mode of registering differences of declination that has been in use at the Berlin Observatory since 1879, and is described by Dr Knarre in the *Zeitschrift für Instrumentenkunde* for July 1881. The instrument is called a declinograph. It has a web moved in declination by a quick-acting screw; the same screw carries a travelling pricker or point. The observer having bisected a star by the wire has simply to compress an india-rubber ball connected by a flexible tube with a thin metal box made on the principle of the vacuum chamber of an aneroid barometer. The expansion of this box so produced brings a sheet of paper in contact with two prickers, one the movable pricker before mentioned, the other a fixed pricker. The action of the vacuum box also automatically shifts the paper (a long roll) by a small quantity at each observation, so that successive observations are recorded in regular order. To obtain the observed differences of declination it is then only necessary to measure with a glass scale (divided for the special telescope to 10″) the distance of each record of the moving pricker from the fixed pricker. It is found, with this declinograph on the Berlin equatorial, that the observed declinations have only a probable error of $\pm 0''\cdot 9$. It is obvious that by using a chronograph in conjunction with this instrument both right ascensions and declinations could be recorded with great accuracy and rapidity.

Miscellaneous Micrometers.

Parallel glass micrometer. Clausen in 1841 (*Ast. Nach.*, No. 414) proposed a form of micrometer consisting of a divided plate of parallel glass placed within the cone of rays from the object-glass at right angles to the telescope axis. One half of this plane remains fixed, the other half is movable. When the inclination of the movable half with respect to the axis of the telescope is changed by rotation about an axis at right angles to the plane of division, two images are produced. The amount of separation is very small, and depends on the thickness of the glass, the index of refraction, and the focal length of the telescope. Secchi (*Comptes Rendus*, xli., 1855, p. 906) gives an account of some experiments with a similar micrometer; and Porro (*Comptes Rendus*, xli. p. 1058) claims the original invention and construction of such a micrometer in 1842. Clausen, however, has undoubted priority. Helmholtz in his "Ophthalmometer" has employed Clausen's principle, but arranges the plates so that both move symmetrically in opposite directions with respect to the telescope axis. Should Clausen's micrometer be employed as an astronomical instrument it would be well to adopt the improvement of Helmholtz.

Ghost micrometer. Burton and Grubb (*Monthly Notices*, vol. xli. p. 59), after calling attention to Lamont's paper (*Jahrbuch der K. S. b. München*, p. 187) and Littrow's paper (*Proc. of Vienna Acad. of Sciences*, vol. xx. p. 253) on a like subject, proceed to describe a most ingenious form of "Ghost Micrometer," in which the *image* of a fine line or lines ruled in (or rather cut through) a silver film deposited on glass is formed at the common focus of an object-glass and eye-piece of a telescope. A faint light being thrown on the outside of the silvered plate, there appear bright lines in the field of view. We have not had an opportunity of testing this, nor Grubb's more recent models; but, should it be found possible to produce such images satisfactorily, without distortion and with an apparatus convenient and rigid in form, such micrometers will probably supersede the filar micrometer. Their absolute freedom from diffraction, the perfect control of the illumination and thickness of the lines, and the accuracy with which it will be possible to construct scales for zone observations will be important features of the new method.

For the use of micrometers in connexion with the microscope, see p. 277 of the present volume. (D. GI.)

MICRONESIA. The term "Micronesia" embraces that region of the Pacific north of the great Melanesian islands, where, either perhaps from a greater or more rapid subsidence, or from the decreasing activity northwards of the coral builders, the islands become, generally speaking, smaller and fewer, and finally cease. Accordingly, excepting the Marianas or Ladrones, which are of volcanic origin, and a few isolated instances of elevation in the Carolines, the Micronesian islands, though many of the groups cover a vast area, are almost without exception very small low coral (atoll) formations. Besides the LADRONE and CAROLINE ISLANDS (*q.v.*) Micronesia includes the Marshall and Gilbert groups, and some geographers include the Anson group, a number of small widely-scattered islets to the west of Hawaii, the Magellan group farther west, and the Bonin Islands north of the Ladrones.[1]

North-easterly winds prevail during the winter months over the Marshalls, Ladrones, and Carolines, except in the extreme west, while between May and September the influence of the monsoon causes unsettled weather from the west, with heavy gales. In the Gilberts the south-east trade-wind brings fine weather at this season.

The ethnological features of Micronesia are much more definite than the geographical, for its populations form one great branch of the fair Polynesian race, distinguished from the other by well-marked differences in appearance, language, and institutions. Its ethnological relations are not thoroughly understood. The proximity of Japan and the Philippines on the west and of the Papuan and South Polynesian islands on the south and south-east suggests, what in fact we find, a combination of elements in different degrees of fusion. In some places the oblique Mongolian eye is noticed, and (along with certain Indo-Chinese customs) there is often a scantiness of beard and general "Malay" look which increases westwards, and seems to imply relations with the archipelago subsequent to the departure thence of the pure Polynesians. In the Gilberts the traces of Polynesian (Samoan) influences are evident, and are confirmed by tradition. Among the Carolines and the Marshalls darker and more savage communities are found, suggesting a Melanesian element, which is further traceable in the Ebon (Marshall) and other languages.

Each of the four groups, from long isolation, has developed peculiarities of its own. The most advanced were the "Chamorros" of the Ladrones, owing to the greater natural resources of the islands, and perhaps more frequent contact with influences from the west; but as a separate people they no longer exist, having been nearly exterminated by the Spaniards in the 17th century. Next in advancement come the Carolines. The general type is a well-proportioned rather slightly built figure, with small and regular features; head high and well-proportioned, but forehead rather retreating, and narrow at the temples; cheek bones and chin slightly prominent; colour somewhat darker than the Polynesians, the Marshalls being darker and more vigorous than the Carolines, while the Gilbert type is still darker and coarser. The upper class greatly surpasses the common people in physique and intelligence.

There is a peculiar division of society into septs or clans, the membership of which constitutes the closest tie. Persons of the same sept must not intermarry, and when two islands or communities meet in war the members of one sept, however widely separated by distance of space or time, will not injure or fight with each other. Each community is usually composed (but there are local differences) of—(1) an upper class of chiefs, from among whom the head (*tamol* or *iros*) is chosen; (2) a lower but still noble class; and (3) common people, mostly without rights of property. These last are only allowed one wife. Assemblies of the chiefs everywhere limit the kingly authority. In the Marshalls the sovereign has lost his control over many of the atolls, and in the Gilberts the above distinctions have nearly disappeared; the headship has lapsed, and, especially in the southern islands, the man of largest substance is the most powerful, and sometimes establishes a local supremacy. Here and there are traces, as in Tonga, of a spiritual sovereign, the descendants probably of a conquered dynasty. Succession is through the female side, which assures to women a certain position,

[1] These islands, which contain a mixed immigrant population, are claimed, and have been recently surveyed, by Japan. But they were annexed to England by Captain Beechey in 1827. (See Von Kittlitz, *Denkwürdigkeiten einer Reise nach . . . . Mikronesien*, &c., vol. ii.)

and leads besides to some curious results (see paper by Kubary in *Das Ausland*, 1880, No. 27). The upper class are the keepers of traditions, boat-builders, leaders of expeditions; tattooing is generally done by them, the amount increasing with a man's rank; the custom here still has definite religious associations. Both sexes are tattooed. The people are singularly amiable and well disposed, but will repay ill usage with treachery. The women (although chastity is not expected before marriage) are somewhat more moral than the Polynesians, and are treated with respect, as are the aged. The natives are polite and hospitable to strangers (except on the poorer and ruder islands), bright and intelligent, active traders, expert cultivators and fishermen. They have a hand-loom from which beautiful fabrics of banana, hibiscus, and other fibres are produced. The Marshall Islanders are the boldest and most skilful navigators in the Pacific. Their voyages of many months' duration, in great canoes sailing with outrigger to windward, well-provisioned, and depending on the skies for fresh water, help to show how the Pacific was colonized. They have a sort of chart, *medo*, of small sticks tied together, representing the positions of islands and the directions of the winds and currents. A two-edged weapon, of which the blade is of sharks' teeth, and a defensive armour of braided sennit, are also peculiar to the islands; a large adze, made of the *Tridacna gigas*, was formerly used in the Carolines, probably by the old builder race.

The languages of Micronesia, though grammatically alike, differ widely in their vocabularies. They have the chief characteristics of the Polynesian, with Malay affinities, and peculiarities such as the use of suffixes and inseparable pronouns and, as in Tagal, of the infix to denote changes in the verb; in the west groups there is a tendency to closed syllables and double consonants, and a use of the palatals *ch*, *j*, *sh*, the dental *th*, and *s* (the last perhaps only in foreign words), which is alien to the Polynesian. These letters are wanting in the Gilbert language, which differs considerably from all the others, and has much greater affinities with the Polynesian.

The religious myths are generally identifiable with the Polynesian, but a belief in the gods proper is overshadowed by a general deification of ancestors, who are supposed from time to time to occupy certain blocks of stone, set up near the family dwelling, and surrounded by circles of smaller ones. These stones are anointed with oil, and worshipped with prayer and offerings, and are also used for purposes of divination, in which, and in various omens, there is a general belief. In the Marshalls, in place of these stones, certain palm trees are similarly enclosed. The spirits also sometimes inhabit certain birds or fishes, which are then *tabu*, as food, to the family; but they will help to catch them for others. All this closely recalls the *karwars* or ancestral images of New Guinea. Temples are very rare, though these blocks of coral are sometimes surrounded by a roofless enclosure opening to the west. The bodies of the dead, and sometimes even of the sick, are despatched to sea westwards, with certain rites; those of the chiefs, however, are buried, for the order has something essentially divine about it; their bodies therefore are sacred, and their spirits naturally assume the position above described. Such a belief greatly strengthens the king's authority, for the spirits of his ancestors are necessarily more powerful than any other spirits. Thus too it comes that the chiefs, and all belonging to them, are tabu as regards the common people. There are various other subjects and occasions of tabu, but the institution has not the oppressive and all-pervading character which it has in Polynesia. Its action is often economical or charitable, *e.g.*, the ripening cocoa-nuts are tabu as long as the bread-fruit lasts, thus securing the former for future use; or it is put on after a death, and the nuts thus saved are given to the family—a kindness to them, and a mark of respect for the dead.

The flora of the Gilbert and Marshall groups is of the usual oceanic character, with close Indo-Malay affinities. It is much poorer than that of the Carolines,[1] with its Moluccan and Philippine elements, and this again is surpassed by that of the Ladrones. In the Gilberts the scattered woods of cocoa-palm and *Pandanus* have little undergrowth, while the south Marshalls, being within the belt of constant precipitation, have a dense growth of (mostly) low trees and shrubs, with here and there a tropical luxuriance and variety unusual on atolls. The *Pandanus* grows wild profusely, and is of exceptional importance, being the chief staple of food, so that the cocoa-nut, which, however, flourishes chiefly in the Gilberts, is used mainly to produce oil for exportation. The bread-fruit grows chiefly in the south Marshalls. The taro (*Arum cordifolium* and others) is cultivated laboriously, deep trenches being cut in the solid rock for its irrigation, but this and other plants of cultivation, and indeed the vegetation generally, fall off in number and quality northwards. Various vegetables are grown on soil imported for the purpose. Marine plants are rare. Wilkes found on Makin Island, Gilbert group, a "fruit resembling the gooseberry," called "teiparu," from which a preserve is made. This seems very like the tipari or Cape gooseberry of India (*Physalis peruviana*). And their *karaku*, a drink made from the sap of the flower-stalk of the cocoa-palm (unfermented before the arrival of Europeans), recalls the arrack of southern Asia.

The fauna, like the flora, becomes poorer eastwards, birds being much more numerous on the high islands than on the atolls, where the few are chiefly aquatic. On Bonabe (Puynipet) out of twenty-nine species eleven are sea birds, and of the remaining eighteen seven are peculiar to the island. From the Pelews fifty-six species are recorded (twelve peculiar), and from the neighbouring Mackenzie group (Ulithi) twenty (six peculiar). Yet curiously no species is recorded common to these two groups and peculiar to them. The common fowl is found everywhere, wild or tame, and in some places is kept for its feathers only. The rat and a *Pteropus* are the only indigenous land mammals. The Indian crocodile is found as far east as the Pelews. There are five or six lizards, including a *Gecko* and *Ablepharus*. Insects are numerous, but of few kinds. Scorpions and centipedes are common, but are said to be harmless.

The houses in the Gilberts and Marshalls (much less elaborate than in the Carolines) consist merely of a thatched roof resting on posts or on blocks of coral about 3 feet high, with a floor at that level, which is reached from an opening in the centre. On this the principal people sleep, and it serves as a storehouse inaccessible to rats, which infest all the islands.

The Marshall archipelago consists of two nearly parallel chains of atolls, from 100 to 300 miles apart, the west known as Ralik, the east as Ratak. They lie between 4° 30′ and 12° N., and between 165° 15′ and 172° 15′ E., and run about N.N.W. and S.S.E. They were discovered in 1529 by Saavedra, who, observing the fine tattooing of the inhabitants (the first allusion to the practice in the Pacific), called them Los Pintados. Among modern voyagers Wallis first visited them in 1767; Captains Marshall and Gilbert reached them in 1788, and Kotzebue (1816) explored them more thoroughly. Each group contains fifteen or sixteen atolls, which range from 2 to 50 miles in circumference. An anomalous feature is reported on some of them, viz., that the greater proportion of land, or at all events of soil, is not found as usual on the windward side of the lagoon, for the prevailing north-east wind sweeps, it is said, the materials of which the soil of such islands is composed across to the lee side. Jaluit Island is the commercial emporium of the whole region. There is a curious tradition on Ebon Island of the Darwinian fact that the atoll once formed the barrier reef of an island now sunk beneath the lagoon. The population of Ratak is about 6000, of Ralik 4000; there is little intercourse between the two groups.

The Gilbert archipelago, discovered by Byron in 1765, is geographically a south continuation of the Marshalls, the channel separating them being 50 leagues wide. It lies between 2° 40′ S. and 3° 20′ N., and between 172° 30′ and 177° 15′ E., and contains sixteen atolls, not including two hilly islands, Banaba and Nawodo, which lie 5° to 6° to the west. Several have good anchorages inside the lagoon, with entrances on the lee side. On some the lee or west reef is wanting, owing to the abrading force of the west storms. During these large trees are washed ashore, their roots containing pieces of fine basalt, of which implements are made. There is a far larger proportion of land to submerged reef and lagoon than in the Marshalls, the land sometimes rising 20 feet above the sea, whereas in the Marshalls the average level of the reef rock is less than a foot above the surface; but, though the supply of fresh water is exceptionally great, in fact enough for the luxury of a bath, the soil (especially in the south) is very much less productive. Yet the population, about 50,000, is exceptionally dense. The usual scattered houses are replaced by compact rows of roofs which, shaded by cocoa-palm, and each with its boat-shed below, line the shore. Their numbers are unchecked either by the constant practice of abortion or by fighting, to which they are much addicted, their weapons being more formidable than those of their neighbours. This exceptional vigour may be due to the decidedly hybrid character of the race. Hawaiian missionaries, under American superintendence, have laboured here since 1857.

See also Findlay's *Sailing Directions for the North Pacific*; Roper's *North Pacific Pilot and Nautical Magazine*, vols. xxxi. and xxxv. Other authorities are Gerland in *Waitz's Anthropologie der Naturvölker*, vol. v.; Meinicke, *Die Inseln des Stillen Oceans*; Hale's *Ethnography and Philology of Wilkes's U. S. Exploring Expedition*; Kotzebue and Chamisso, *Entdeckungsreise in die Südsee*; *Proc. Zool. Soc.*, 1872 and 1877. (C. T.)

MICROPHONE. See TELEPHONE.

[1] About 180 species have been observed on Kusaie, one-fourth of all the plants being ferns.

MICROSCOPE

THE microscope is an optical instrument for the examination of minute objects or parts of objects, which enlarges the visual pictures formed upon the retina of the observer by the rays proceeding from them.

Microscopes are distinguished as *simple* or *compound*. In the former, the rays which enter the eye of the observer come from an object brought near to it after refraction through either a single lens or a combination of lenses acting as a single lens,—its action as a "magnifier" depending on its enabling the eye to form a distinct image of the object at a much shorter distance than would otherwise be possible. The latter consists of at least two lenses, so placed relatively to the object, to the eye, and to one another that an enlarged image of the object, formed by the lens placed nearest to it (the "object-glass"), is looked at through the lens nearest the eye (the "eye-glass"), which acts as a simple microscope in "magnifying" it; so that the compound microscope may be described as a simple microscope used to look at an enlarged image of the object, instead of at the object itself.

History of the Simple Microscope.—Any solid or liquid transparent medium of lenticular form, having either one convex and one flat surface or two convex surfaces whose axes are coincident, may serve as a "magnifier,"—what is essential being that it shall have the power of so refracting the rays which pass through it as to cause widely diverging rays to become either parallel or but slightly divergent. Thus if a minute object be placed on a slip of glass, and a single drop of water be carefully placed upon it, the drop will act as a magnifier in virtue of the convexity of its upper surface; so that when the eye is brought sufficiently near it (the glass being of course held horizontally, so as not to distort the spherical curvature of the drop) the object will be seen much enlarged. And if a small hole be made in a thin plate of metal, and a minute drop of water be inserted in it, this drop, having two convex surfaces, will serve as a still more powerful magnifier. There is reason to believe that the magnifying power of transparent media with convex surfaces was very early known. A convex lens of rock-crystal was found by Layard among the ruins of the palace of Nimrud. And it is pretty certain that, after the invention of glass, hollow spheres blown of that material and filled with water were commonly used as magnifiers (comp. vol. xiv. p. 577). The perfection of gem-cutting shown in ancient gems, especially in those of very minute size, could not have been attained without the use of such aids to the visual power; and there can be little doubt that the artificers who could execute these wonderful works could also shape and polish the magnifiers best suited for their own or others' use. Though it is impossible to say when convex lenses of glass were first made by grinding, it is quite certain that they were first generally used to assist ordinary vision as "spectacles," the use of which can be traced back nearly six centuries; and not only were spectacle-makers the first to produce glass magnifiers (or simple microscopes), but by them also the telescope and the compound microscope were first invented. There seems no reason to believe, however, that lenses of very high magnifying power (or short focus) were produced until a demand for them had been created by the introduction of the compound microscope, in which such lenses are required as "object-glasses"; and the difficulty of working lenses of high curvature with the requisite accuracy led in the first instance to the employment of globules made by fusing the ends of threads of spun glass. It was in this way that Robert Hooke shaped the minutest of the lenses with which he made many of the numerous discoveries recorded in his *Micrographia*; and the same method was employed by the Italian microscopist Father Di Torre. It seems to have been Leeuwenhoek that first succeeded in grinding and polishing lenses of such short focus and perfect figure as to render the simple microscope a better instrument for most purposes than any compound microscope then constructed,—its inferiority in magnifying power being more than counterbalanced by the superior clearness of the retinal picture. And, in despair of any such modification in the compound form as should remove the optical defects which seemed inherent in its plan of construction, scientific opticians and microscopic observers alike gave their chief attention for a considerable period to the improvement of the simple microscope. In order that the nature of these improvements may be understood, the principle of its action must be first explained.

The normal human eye has a considerable power of self-adjustment, by which its focal length is so varied that it forms equally distinct pictures of objects brought within ordinary reading distance (say 10 inches) and of objects whose distance is many times that length,—the size of the visual picture of any object diminishing, however, with the increase in the distance to which it is removed, and the amount of detail distinguishable in it following the same proportion. Thus a man who looks across the street at a placard posted on the opposite wall may very distinctly see its general form and the arrangement of its heading, and may be able to read what is set forth in its largest type, whilst unable to separate the lines, still more to read the words, of what is set forth below. But by crossing the street so as to bring his eye nearer the picture he finds himself able to read the smaller type as easily as he before read the larger,—the visual picture on his retina having been magnified, say 10 times in linear dimension, by the reduction of the distance of his eye from 40 feet to 4. Similarly, if he holds a page of excessively minute type at arm's length (say 40 inches) from his eye, he may be unable to read it, not because his eye does not form a distinct retinal picture of the page at that distance, but because the details of that picture are too minute for him to distinguish them. But if he brings the page from 40 inches to 10 inches distance, he may be able to read it without difficulty,—the retinal picture being enlarged four times linear (or sixteen times superficial) by this approximation. Now the rays that enter the eye from each point of a remote object diverge so little as to be virtually parallel; but the divergence increases with the approximation of the object to the eye, and at 10 inches the angle of their divergence is as wide as permits the ordinary eye to bring them to a focus on the retina. When the object is approximated more closely, an automatic contraction of the pupil takes place, so that the most diverging rays of each pencil are cut off, and a distinct picture may be formed (though not without a feeling of strain) when the object is (say) from 5 to 8 inches distant,—giving still greater minuteness of visual detail in conformity with the increase of size. A further magnifying power may be obtained without the interposition of any lens, by looking at an object, at 2 or 3 inches distance, through a pin-hole in a card; for by thus cutting off the more divergent rays of each pencil, so as to admit only those which can be made to converge to a focus on the retina at that distance, a distinct and detailed picture may be obtained, though at the expense of a great loss of light. Moreover,

although an ordinary eye does not form a distinct picture of an object at less than from 10 to 6 inches distance, a "myopic" or "short-sighted" eye (whose greater refractive power enables it to bring rays of wider divergence to a focus on the retina) may form an equally distinct picture of an object at from 5 to 3 inches distance; and, as the linear dimensions of that picture will be double that of the preceding, the object will be "magnified" in that proportion, and its details more clearly seen.

The effect of the interposition of a convex lens between the eye and an object nearly approximated to it primarily consists in its reduction in the divergence of the rays of the pencils which issue from its several points, so that they enter the eye at the moderate divergence which they would have if the object were at the ordinary nearest limit of distinct vision. And, since the shorter the focus of the lens the more closely may the object be approximated to the eye, the retinal picture is enlarged, causing the object to appear magnified in the same proportion. Not only, however, are the component rays of each pencil brought from divergence into convergence, but the course of the pencils themselves is changed, so that they enter the eye under an angle corresponding to that under which they would have arrived from a larger object situated at a greater distance; and thus, as the picture formed upon the retina by the small object *ab*, fig. 1, corresponds in all

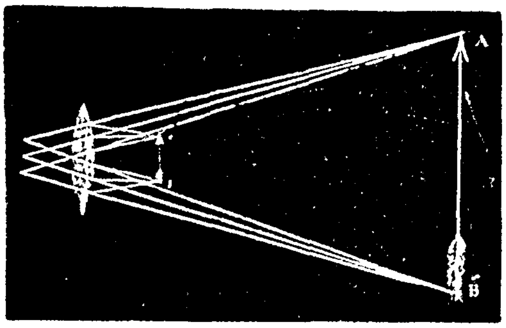


FIG. 1.—Action of Simple Microscope.

respects with that which would have been made by the same object AB of several times its linear dimension viewed at the nearest ordinary limit of distinct vision, the object is seen (by the formation of a "virtual image") on a magnified scale.

It is obvious that the "magnifying power" of any convex lens so used is measured by the ratio between the dimensions of the retinal picture formed with its assistance and those of the picture formed by the unaided eye. Thus, if by the use of a convex lens having 1 inch focal length we can form a distinct retinal image of an object at only an inch distance, this image will have ten times the linear dimensions of that formed by the same object at a distance of 10 inches, but will be only eight times as large as the picture formed when the object can be seen by ordinary vision at 8 inches distance, and only four times as large as the picture of the same object formed by a myopic eye at a distance of 4 inches. It is usual to estimate the magnifying power of single lenses (or of combinations that are used as such) by the number of times that their focal length is contained in 10 inches,—that of 1 inch focus being thus taken as ten times, that of $\frac{1}{10}$ inch as one hundred times, and so on. But the rule is obviously arbitrary, as the actual magnifying power varies in each individual with the nearest limit of distinct vision. Thus for the myopic who can see an object clearly at 4 inches distance, the magnifying powers of a 1 inch and $\frac{1}{10}$ inch lens will be only 4 and 40 respectively. The amplifying power of every single convex lens, however, is impaired (1) by that inability to bring to the same focus the rays which fall upon the central and the marginal parts of its surface which is called "spherical aberration," and (2) by that dispersion of the rays of different wave-lengths, in virtue of their different refrangibilities, which produces coloured fringes around the points and lines of the visual picture, and is therefore called "chromatic aberration" (see LIGHT). These aberrations increase with the "angle of aperture" given to the lens, that is, with the proportion between the diameter of its actual "opening" and the focal distance of the object; and thus, when a single lens of very short focus is used in order to gain a high magnifying power, such a reduction of its aperture by a perforated diaphragm or "stop" becomes necessary (in order, by excluding the peripheral rays, to obtain tolerable "definition" with freedom from false colour) that the amount of light admitted to the eye is so small as only to allow the most transparent objects to be thus viewed, and these only very imperfectly. In order to remedy this drawback, it was proposed by Sir D. Brewster to use instead of glass, in the construction of simple microscopes, such transparent minerals as have high refractive with low dispersive power; in which case the same optical effect could be obtained with lenses of much lower curvature, and the aperture might be proportionately enlarged. This combination of qualities is found in the diamond, whose index of refraction bears such a proportion to that of glass that a diamond lens having a radius of curvature of 8 would give the same magnifying power as a glass lens whose radius of curvature is 3, while the "longitudinal aberration" (or distance between the foci of central and of marginal rays) would be in a diamond lens only one-ninth of that of a glass lens having the same power and aperture. Putting aside, however, the costliness of the material and the difficulty of working it, a source of imperfection arises from a frequent want of homogeneousness in the diamond crystal, which has proved sufficient to make a lens worked from it give a double or even a triple image. Similar attempts made by Mr Pritchard with sapphire proved more successful; and, as a sapphire lens having a radius of curvature of 5 has the same focus and gives the same magnifying power as a crown-glass lens having a radius of 3, it was found to bear a much larger aperture without serious impairment by either spherical or chromatic aberration. As the sapphire, however, possesses the property of double refraction, the duplication of the markings of the object in their retinal image constitutes a very serious drawback to the utility of lenses constructed of this mineral; for, though the double refraction may be reduced almost to nothing by turning the convex side of the lens towards the object, yet, as this is the worst position in regard to spherical aberration, more is lost than is gained. Fortunately, however, for biological investigators working with simple microscopes, the introduction of the Wollaston doublet superseded the necessity of any further attempts at turning costly jewels to account as high-power magnifiers.

Wollaston Doublet.—This consists of a combination of two plano-convex lenses, whose focal lengths (as directed by Dr Wollaston) should be as 3 to 1, with their plane sides turned towards the object,—the smaller lens being placed lowest, and the upper lens at a distance of one and a half times its focal length above it. This construction, however, has been subsequently improved—(1) by the introduction of a perforated diaphragm between the lenses; (2) by a more effective adjustment of the distance between the two lenses, which seems to be most satisfactory when it equals the difference of their respective focal lengths, allowance being made for their thickness; and (3) by the division of the power of the lower lens (when a shorter focus than $\frac{1}{10}$ inch is required) into two, so as to form a "triplet." When combinations of this kind are well

constructed, spherical aberration is almost wholly got rid of, and chromatic dispersion is so slight that the angle of aperture may be considerably enlarged without much sacrifice of distinctness. Such "doublets" and "triplets," having been brought into use in England while the compound microscope still retained its original imperfections, proved very serviceable to such as were at that time prosecuting minute biological investigations: for example, the admirable researches of Dr Sharpey on ciliary action in animals (1830–35) and Mr Henry Slack's beautiful dissections of the elementary tissues of plants, as well as his excellent observations on vegetable cyclosis (1831), were made by their means. No one, however, would now use Wollaston "doublets" or "triplets" of high power in place of a compound achromatic microscope; and for the simple microscopes of low power that are useful either for dissecting or for picking out minute specimens (such as diatoms) other constructions are preferable, as giving a larger field and more light. As a hand-magnifier the "Coddington" lens—which is a sphere of glass with a deep groove ground out of its equatorial portion—has many advantages.[1] By making this groove sufficiently deep, both spherical and chromatic aberrations can be rendered almost insensible; and, as the rays falling on any part of the spherical surface can only pass to the eye either through or near the centre, the action of every part of that surface is the same, so that the image of the object will be equally distinct (when properly focussed) whether its parts lie nearer to the axis of the sphere or more remote from it, or the axis be itself turned to one side or the other. Again, it was mathematically shown by Sir John Herschel in 1821 that by the combination of a meniscus with a double convex lens—the four surfaces of these lenses having certain proportionate curvatures—spherical aberration could be entirely extinguished for rays parallel to the axis, the combination being thus an "aplanatic" doublet, while another combination, which he termed a "periscopic" doublet, gives a remarkable range of oblique vision with low powers, and almost entirely extinguishes chromatic aberration, although at the expense of residual spherical aberration. These combinations have been mounted both as hand-magnifiers and as single microscopes, for both which purposes they are much superior to single lenses of the same magnifying power. But such combinations have been greatly improved by the introduction of concaves of flint glass, so as to render them achromatic as well as aplanatic; and nothing, according to the writer's experience, can now be used with greater advantage for all the purposes answered either by the simple microscope or the hand-magnifier than Browning's "platyscopic" lenses or the "achromatic doublets" of Steinheil of Munich. Each of these combinations gives a large flat field, with plenty of light, admirable definition, and freedom from false colour.

At the period when "doublets" of very short focus were used in order to obtain high magnifying power, it was requisite to mount these on such a stand as would enable the focal adjustment to be made, and would admit the use of a special illuminating apparatus with great exactness. But now that comparatively low powers only are employed the ordinary rack-and-pinion movement is quite sufficient for their focal adjustment, and nothing more is required for the illumination of the object than a concave mirror beneath the stage when it is transparent, and a condensing lens above when it is opaque. The various patterns of simple microscope now made by different makers vary in their construction, chiefly in regard to portability, the size of their stages, and the mode in which "rests" or supports to the hands are provided. These, in Continental instruments, are very commonly attached to the stage; but, unless the stage itself and the pillar to which it is fixed are extremely massive, the resting of the hands on the supports is apt to depress the stage in a degree that affects the focal adjustment; and where portability is not an object it seems better that the hand-supports should be independent of the stage. For a laboratory microscope, the pattern represented in fig. 2 has been found very convenient,—the framework being of mahogany or other hard wood, the stage

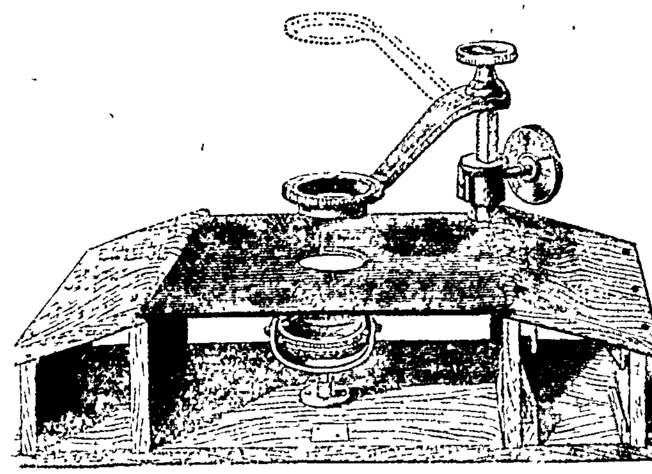


FIG. 2.—Laboratory Dissecting Microscope.

being large enough to admit a dissection or carry a water-trough of considerable size, and the bent arm that carries the "powers" being made capable of reversion, so as to permit the use of lenses of very long as well as of very short focus. As it is desirable that the stage should not be acted on chemically by sea-water, acids, or other reagents, it may be made either of a square of plate-glass or of a plate of ebonite with an aperture in the middle; and either of these may be made to slide in grooves in the side supports, so that one may be substituted for the other. The arm may be easily made (if desired) to carry the body of a compound microscope, so as to apply it to the examination of objects dissected or otherwise prepared under the simple microscope, without transferring them to another instrument. A portable form of simple microscope is shown in fig. 30.

Compound Microscope.—The placing of two convex lenses in such relative positions that one should magnify an enlarged image of a small near object formed by the other naturally soon followed the invention of the telescope, and seems to have first occurred to Hans Zansz or his son Zacharias Zansz, spectacle-makers at Middelburg in Holland, about 1590. One of their compound microscopes, which they presented to Prince Maurice, was in the year 1617 in the possession of Cornelius Drebell of Alkmaar, who then resided in London as mathematician to king James I. In order to make clear the successive stages by which the rude and imperfect microscope of that period has, after remaining for two centuries unimproved in any essential particular, been developed within the last half-century into one of the most important instruments of scientific research that the combination of theoretical acumen and manipulative skill has ever produced, it is necessary to explain the principle of its construction, and to show wherein lay the imperfection of its earlier form.

In its simplest construction, as already stated, the compound microscope consists of only two lenses,—the "object-glass" CD, fig. 3, which receives the light-rays direct from the object AB placed near it, and forms an enlarged but reversed image A′B′ at a greater distance on the other side, and the "eye-glass" LM, which receives the rays that diverge from the several points of this image as if they proceeded from the points of an actual object occupying the position and enlarged to the dimensions A′B′, and brings these to the eye at E, so altering their course as to

[1] It is difficult to understand how the name of Coddington came to be attached to the grooved sphere, seeing that he neither was nor claimed to be the inventor of it. Dr Wollaston's first "doublet" consisted of a pair of plano-convex lenses with their plane surfaces opposed to each other, and a diaphragm with central aperture placed between them. Sir D. Brewster showed that this construction is most advantageous when the two lenses are hemispheres, and the central aperture between their two plane surfaces is filled up by a transparent cement having the same refractive index as glass. And from this the transition is obvious to the grooved sphere, which had been made for Sir D. Brewster long before the high commendation it received from Mr Coddington brought it into general repute.

act as a simple microscope in magnifying that image to the observer. It was early found useful, however, to interpose another lens FF, fig. 4 (the "field-glass"), between the object-glass and the image formed by it, for the purpose of giving such a slight convergence to the pencil of rays as shall reduce the dimensions of the image, and thus allow a larger part of it to come within the range of the eye-

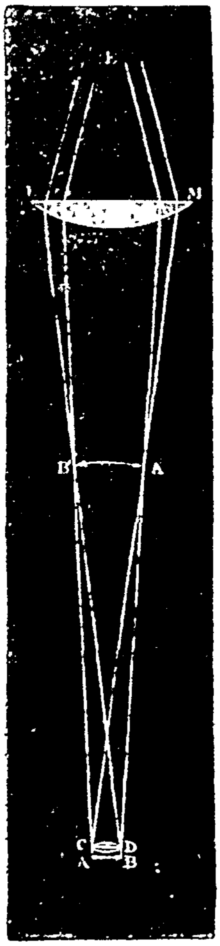


FIG. 3.—Diagram of Simplest Form of Compound Microscope.

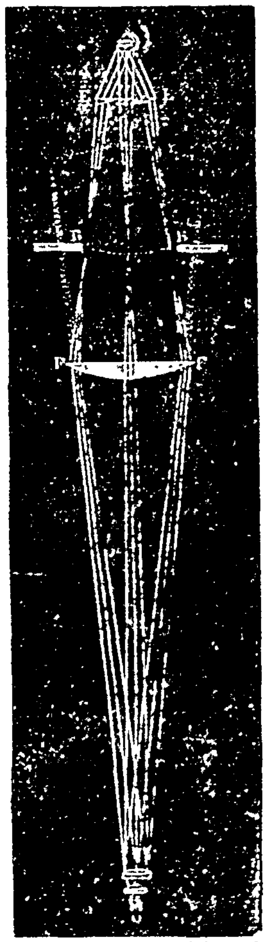


FIG. 4.—Diagram of Complete Compound Microscope.

glass, so that more of the object can be seen at once. And it was soon perceived that the eye-glass and the field-glass might be advantageously combined into an "eye-piece," in which a perforated diaphragm might be inserted at the focal plane of the image (*i.e.*, in the focus of the eye-glass), so as, by cutting off the peripheral portion of the field of view, to limit it to what can be seen with tolerable distinctness.

It is obvious that the magnifying power of such an instrument would depend (1) on the proportion between the size of the image formed at BB and that of the actual object, and (2) upon the magnifying power of the eye-glass. And further the proportion which the size of the image bears to that of the object depends upon two factors,—(1) the focal length of the object-glass, and (2) the distance between the object-glass and the plane BB occupied by the image it forms. If we diminish the focal length of the object-glass, the object must be brought nearer to it, so that, while the distance of the image on the other side remains unchanged, that distance comes to bear a larger proportion to the distance of the object, and the size of the image is augmented in a corresponding ratio. On the other hand, the object-glass remaining unchanged, the distance at which it forms the image of the object can be increased by a lengthening of the tube of the microscope; and, as this involves a shortening of the distance between the object-glass and the object, the proportion which the former bears to the latter is augmented, and the image is correspondingly enlarged. Thus an increase in the magnifying power of the compound microscope may be gained in three modes, which may be used either separately or in double or triple combination,—viz., (1) shortening the focus of the object-glass, (2) lengthening the tube of the microscope, and (3) increasing the magnifying power of the eye-glass by shortening its focus. This, it may be remarked, also lengthens the distance of the image from the object-glass, by bringing the focal plane BB nearer the eye-glass. The second of these methods was not unfrequently used in the older microscopes, which were sometimes made to draw out like telescopes, so as to increase the amplifying power of their object-glasses. But, whilst very inconvenient to the observer, such a lengthening of the one distance involved such a shortening of the other as greatly impaired the distinctness of the image by increasing the aberrations of the object-glass, so that this method came to be generally abandoned for one of the other two.

When lenses of from 1 to 4 inches focus were used as object-glasses, and their apertures were restricted by a stop to the central part of each, tolerably distinct images were given of the larger structural arrangements of such objects as sections of wood or the more transparent wings of insects,—which images would bear a further moderate enlargement by the eye-glass without any serious deterioration either by want of definition or the introduction of colour-fringes. But when lenses of less than 1 inch focus were employed in order to obtain a higher magnifying power, the greater obliquity of the rays so greatly increased their aberrations that defective definition and the introduction of false colours went far to nullify any advantage obtainable from the higher amplification; while the limitation of the aperture required to keep these aberrations within even moderate limits occasioned such a loss of light as most seriously to detract from the value of the picture. On the other hand, the use of deeper eye-pieces to enlarge the images formed by the object-glasses not only brought out more strongly all the defects of those images, but introduced a new set of errors of their own, so that very little was gained by that mode of amplification. Hence many of the best of the older microscopists (notably LEEUWENHOEK, *q.v.*) made some of their most valuable discoveries by the use of the simple microscope; and the amount of excellent work thus done surprises every one who studies the history of microscopic inquiry. This was still more the case, as already stated, when the use of single lenses of very short focus was superseded by the introduction of the Wollaston doublet. And the substitution of these doublets for the single lenses of object-glasses, while the single lens of the eye-glass was replaced by a Herschel's aplanatic doublet, and the field-glass was a convex lens whose two curves had the proportion of 1 : 6 (the form of least spherical aberration), constituted the greatest improvement of which the instrument seemed capable in pre-achromatic times.[1]

It has been only within the last sixty years (1820–30) that the microscope has undergone the important improvement which had been worked out by Dollond in the refracting telescope more than sixty years previously,—namely, the correction of the chromatic aberration of its objectives by the combination of concave lenses of flint-

[1] This combination was made in the first microscope of which the writer became possessed, about the year 1830; and he well recollects the great superiority to any compound microscope of the old construction which was proved by its power of separating the lines on the *Menelaus* scale, and of bringing into view the details of the structure of animalcules, with a clearness that only an achromatized object-glass could surpass.

glass with convex lenses of crown, while their spherical aberration is corrected by the combination (as in Herschel's aplanatic doublet) of convex and concave surfaces of different curvatures. The minute size and high curvature of the lenses required as microscopic objectives were long considered as altogether precluding the possibility of success in the production of such combinations, more especially as the conditions they would have to meet differ altogether from those under which telescopic object-glasses are employed. For the rays from distant objects fall upon the latter with virtual parallelism; and the higher the power required the longer is the focus given to them, and the smaller is the deflexion of the rays. In the microscope, on the other hand, the object is so closely approximated to the objective that the rays which proceed to it from the latter have always a very considerable divergence; and the deflexion to which they are subjected increases with that reduction of the focal length of the objective which is the necessary condition of the increase of its magnifying power. And thus, although the telescopic "triplet" worked out by Dollond (consisting of a double-concave of flint glass, interposed between two double-convex lenses of crown) can be so constructed as to be not only completely aplanatic (or free from spherical aberration) but almost completely achromatic (or free from chromatic aberration), this construction is only suitable for microscopic objectives of long focus and small angular aperture, the rays falling on which have but a very moderate divergence. And though, as will presently appear, some of the early attempts at the achromatization of the microscope were made in this direction, it was soon abandoned for other plans of construction, which were found to be alike theoretically and practically superior.

It seems to have been by Professor Amici, then of Modena, about 1812, that the first attempts were made at the achromatization of microscopic objectives; but, these attempts not proving successful, he turned his attention to the production of a reflecting microscope, which was a decided improvement upon the non-achromatized compound microscopes then in use. In the year 1820, however, the subject was taken up by Selligues and Chevalier of Paris, who adopted the plan of superposing three or four combinations, each consisting of a double-convex of crown cemented to a plano-concave of flint. The back combination (that nearest to the eye) was of somewhat lower power than those placed in front of it, but these last were all of the same focus, and no attempt was made by these opticians to vary the construction of the several pairs thus united, so as to make them correct each others' aberrations. Hence, although a considerable magnifying power could be thus obtained, with an almost complete extinction of chromatic aberration, the aperture of these objectives could not be greatly widened without the impairment of the distinctness of the image by a "coma" proceeding from uncorrected spherical aberration.

In ignorance, it would appear, of what was being done by the Paris opticians, and at the instigation of Dr Goring (a scientific amateur), Mr Tulley—well known in London as an able constructor of telescopic objectives—began, about the year 1824, to work object-glasses for the microscope on the telescopic plan. After many trials[1] he succeeded, in 1825, in producing a triplet of $\frac{9}{10}$ inch focus, admitting a pencil of 18°, which was so well corrected as to perform very satisfactorily with an eye-piece giving a magnifying power of 120 diameters. He afterwards made a similar triplet of shorter focus, which, when placed in front of the previous one, increased the angle of the transmitted pencil to 38°, and bore an eye-piece giving a magnifying power of 300 diameters. These triplets are said by Mr Ross to have never been exceeded by any similar combinations for accurate correction throughout the field.

Having come into possession, at the end of 1826, of an objective of Chevalier's construction, Mr J. J. Lister carefully examined its properties, and compared them with those of Tulley's triplets; and this comparison having led him to institute further experiments he obtained results which were at first so conflicting that they must have proved utterly bewildering to a less acute mind,[2] but which finally led him to the enunciation of the principle on which all the best microscopic objectives are now constructed. For he discovered that the performance of such composite objectives greatly depends upon the relative position of their component combinations,—the effect of the flint plano-concave upon the spherical aberration produced by the double-convex of crown varying remarkably according to the distance of the luminous point from the front of the objective. If the radiant is at a considerable distance, the rays proceeding from it have their spherical error under-corrected; but, as the source of light is brought nearer to the glass, the flint lens produces greater proportionate effect, and the under-correction diminishes, until at length a point is reached where it disappears entirely, the rays being all brought to one point at the conjugate focus of the lens. This, then, is one aplanatic focus. If, however, the luminous point is brought still nearer to the glass, the influence of the flint continues for a time to increase, and the opposite condition of over-correction shows itself. But, on still further approximation of the radiant, the flint comes to operate with less effect, the excess of correction diminishes and at a point still nearer to the glass vanishes, and a second aplanatic focus appears. From this point onwards under-correction takes the place of over-correction, and increases till the object touches the surface of the glass. As every such doublet, therefore, has two aplanatic foci for all points between which it is over-corrected, while for all points beyond it is under-corrected, the optician is enabled to combine two or more doublets with perfect security against spherical error. This will be entirely avoided if the rays be received by the front glass from its shorter aplanatic focus, and transmitted through the back glass in the direction of its longer aplanatic pencil. By the approximation of the two doublets over-correction will be reduced, while their separation will produce under-correction; and thus, by merely varying the distance between two such combinations, the correction of the spherical error may be either increased or diminished according to a definite rule. Slight defects in one glass may thus be remedied by simply altering its position in relation to the other,—an alteration which may be made with very little disturbance of the colour-correction. This important principle was developed and illustrated by Mr Lister in a memoir read to the Royal Society on January 21, 1830, *On some Properties in Achromatic Object-glasses, applicable to the Improvement of the Microscope*; and it was by working on the lines there laid down, that the three London opticians Ross,[3] Powell, and James Smith soon pro-

[1] It is due to Mr Joseph J. Lister to mention that Tulley's final success with this low power seems to have been attained by working on a suggestion given him by that gentleman. See *Monthly Microscopical Journal*, vol. iii. (1870), p. 134.

[2] Thus he found that, while each of Chevalier's doublet combinations, when used singly, presented a "bur" or "coma" outwards, this coma, instead of being exaggerated by the combination of two of these doublets, was much diminished. On the other hand, while two of Tulley's triplets, each of which performed admirably by itself, were used together, the images of all objects not in the centre presented a strong bur inwards with an under-correction of colour.

[3] In 1837 Mr Lister gave Mr Ross a projection for an objective of $\frac{1}{8}$ inch focus, in which a triple front was combined with two doublets. The great superiority of this lens, admirably executed by Mr Ross, caused him to adopt its plan as the standard one for high powers; and it is still in general use,—the back lens also being sometimes made as a triplet.

duced microscopic objectives that surpassed any then constructed on the Continent, while the subsequent adoption of the same principles by French and German opticians, as also by Professor Amici of Florence, soon raised their objectives to a corresponding level.

It has proved more advantageous in practice to make the several components of an achromatic objective correct each others' aberrations than to attempt to render each perfect in itself; and the mode in which this is accomplished will vary with the focus and angular aperture given to each combination. Thus, while a single "telescopic triplet" answers very well for the lowest power usually made (4 inches focus), and the same plan may be used—though at the sacrifice of angular aperture—for objectives of 3 inches, 2 inches, and even 1 inch focus, the best performance of these powers requires the combination of two doublets. And, while this last system also serves for objectives of ⅔ inch and ½ inch of low angle, a third component is required for giving to these objectives the aperture that renders them most serviceable, as well as for all higher powers. Instead of combining three achromatic doublets, however, many makers prefer placing in front a plano-convex of crown, and adding a third lens of crown to the doublet at the back, still using a doublet in the middle,—the whole combination thus consisting of six lenses, four of crown and two of flint. Further, Mr Wenham has shown that the whole colour-correction may be effected in the middle by interposing a double concave of dense flint between two double-convex lenses of crown,—the back lens, as well as the front, being then a plano-convex of crown, making five lenses in all. This plan of construction, though suitable to objectives of moderate angular aperture, and advantageous in regard to comparative simplicity and economy of construction, does not seem so well adapted for objectives to which the largest attainable aperture is to be given,—these being usually constructed with a triplet in front, a doublet in the middle, and a triplet at the back, so as to consist of eight separate lenses. And the first-class constructors of achromatic objectives in the United States usually place in front of these, in their highest powers, a single plano-convex of crown, by the addition of which a greater working distance can be obtained. But, as every such addition increases the liability to error from imperfections in the centring and grinding of the lenses (as well as loss of light by the partial reflexion of oblique rays from their surfaces), it is obvious that the most exact workmanship, involving a proportionate costliness, is required to bring out the full effect of such complex construction. And where angular aperture is regarded as the quality of primary importance it will be usually found preferable to have recourse to objectives constructed on either the "water" or the "oil" immersion system, to be presently described.

The great increase thus attained in the perfection of the corrections of microscopic objectives for both spherical and chromatic aberration of course rendered it possible to make a corresponding increase in their angular aperture. The minute scales of the wings of butterflies and other insects were naturally among the objects much examined; and it was soon perceived that certain lines and other markings became clearly discernible on these scales with objectives of what was then considered large angle which were utterly undistinguishable with non-achromatized microscopes (however high their magnifying power), and very imperfectly shown under achromatic objectives of small angle. Hence these scales came to be used as "test-objects," for judging of the "definition" and "resolving power" of microscopic objectives,—the former property consisting in the clearness, sharpness, and freedom from false colour of the microscopic images of boundary lines, and depending on the accuracy with which the aberrations are corrected, while the latter term designates that power of separating very closely approximated markings which is now known to be a "function" of aperture. The insect-scales formerly most valued for these purposes were those of the *Morpho menelaus* (fig. 5) and the similarly lined scales of the *Polyommatus argus* (azure-blue), the "battledoor" scales of the same butterfly (fig. 6), the ribbed scales of the *Lepisma saccharina* (sugar-louse), and the minute and peculiarly marked scales of the *Lepidocyrtus curvicollis* (fig. 7), commonly known as the *Podura*. The writer recollects the time when the satisfactory "resolution" of the first three of these tests was considered a sufficient proof of the goodness of even high-power objectives, and when the *Podura*-markings, if visible at all, could only be distinguished as striæ. The further opening-out of the aperture, however, enabled these striæ to be resolved into rows of "exclamation marks"; and, while there is still some uncertainty as to the precise structure of which these markings are the optical expression, practical opticians are generally agreed that the *Podura*-scale is very useful as a test for definition, with even the highest objectives, though it only serves as a test for a very moderate degree of resolving power. For the latter purpose it has been completely superseded by the closely approximated markings of the silicified envelopes of certain diatoms (which, however, show themselves in very different aspects according to the conditions under which they are viewed, figs. 8–11), and also by lines artificially ruled on glass, as in Nobert's "test-plate," the number of lines in the nineteen bands of which is stated by M. Nobert to range from 1000 to 10,000 to a Paris line, while Dr Royston Pigott gives the numbers in an English inch as 11,529 to the inch in the first band, and 112,595 in the nineteenth. This last dimension (as will afterwards appear) approaches the minimum distance at which such markings are theoretically separable by any magnifying power of the microscope.

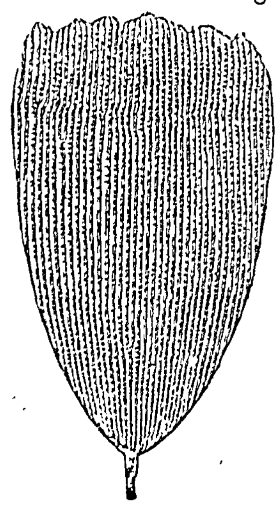


Fig. 5.—Scale of *Morpho menelaus*.

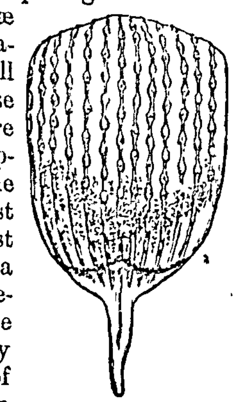


Fig. 6. — Battledoor Scale of *Polyommatus argus*.

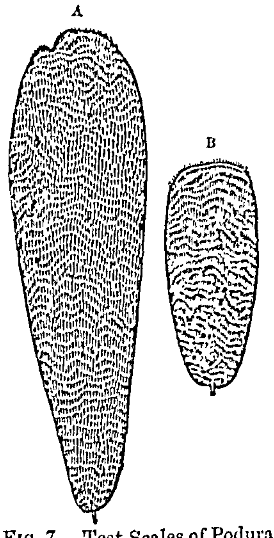


Fig. 7.—Test-Scales of Podura (*Lepidocyrtus curvicollis*). A, large, strongly marked scale; B, small scale, more faintly marked.

The enlargement of the angle of aperture of microscopic objectives and the greater completeness of their corrections, which were obtained in the first instance by the adoption of Mr Lister's principles, and were demonstrated by the resolution of the test-objects then in use, soon rendered sensible an imperfection in their performance under certain circumstances, which had previously passed unnoticed; and the

important discovery was made by Mr Andrew Ross that a very decided difference exists in the precision of the image according as the object is viewed with or without a covering of thin glass, as also according as this cover is thin or thick.[1] As this difference increases in proportion to the widening of the aperture, it would obviously be a

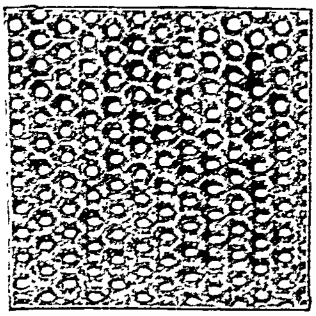


Fig. 8.

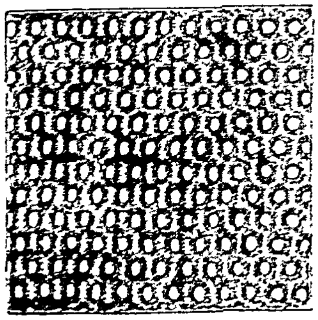


Fig. 9.

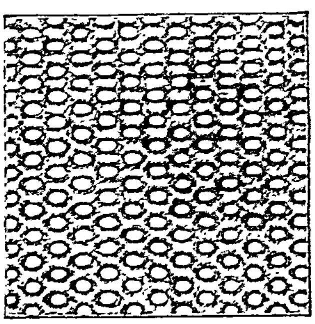


Fig. 10.

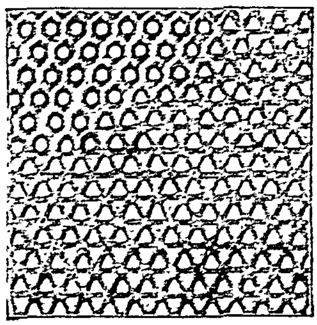


Fig. 11.

Portions of Siliceous Valve of *Pleurosigma angulatum*, from a Photograph taken by Central Illumination. Magnified 2000 diameters.

source of great error and embarrassment if a means could not be found for its rectification. Its optical source, however, having been found by Mr Ross to lie in the "negative aberration" which is produced in the rays proceeding from the object to the front glass of the objective by the interposition of the plane-glass cover, and which increases with its thickness, his practical ability enabled him at the same time to indicate the remedy, which consists in under-correcting the front lens and over-correcting the two posterior combinations, and in making the distance between the former and the latter capable of adjustment by means of a screw-collar, as shown in fig. 12. For when the front pair is approximated most nearly to the next, and its distance from the object is increased, its excess of positive aberration is more strongly exerted upon the other two pairs than it is in the contrary conditions, and thus neutralizes the negative aberration produced by the interposition of the covering-glass. This correction is not needed for objectives of low or medium power and small angle of aperture; but it should always be provided when the angle exceeds 50°,—unless (as is now generally done

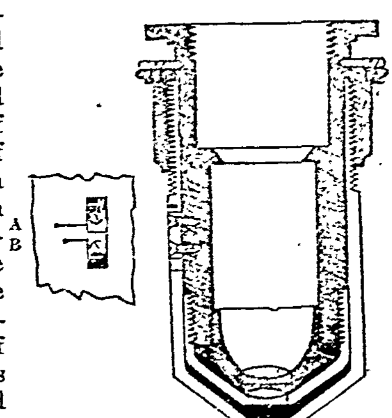


Fig. 12.—Section of Adjusting Achromatic Object-Glass. A, uncovered; B, covered.

in the case of objectives constructed for students' use) the maker adjusts them originally, not for uncovered objects, but for objects covered with glass of a standard thickness, say 0·005 or 0·004 inch. A departure from that standard to the extent of one or two thousandths of an inch in either direction, though extremely injurious to the performance of objectives whose aperture is 125° or more, scarcely makes itself perceptible in those of 90° or 100°. And the same may be said in regard to the immersion-objectives next to be described, which are peculiarly suitable to the purposes of minute histological research.

Immersion System.—It was long since pointed out by Professor Amici that the introduction of a drop of water between the front surface of the objective and either the object itself or its covering-glass would diminish the loss of light resulting from the passage of the rays from the object or its covering-glass into air, and from air into the front glass of the objective. It was obvious to him, moreover, that when the rays enter the object-glass from water, instead of from air, both its refractive and its dispersive action will be so greatly changed as to need an important constructive modification to meet the new condition. This modification seems never to have been successfully effected by Amici himself; but his idea was taken up by the two eminent Paris opticians, MM. Hartnack and Nachet, who showed that the application of what is now known as the "immersion system" to objectives of short focus and large angular aperture is attended, not merely with the advantages expected by Professor Amici, but with others on which he did not reckon. As the loss of light by the reflexion of a portion of the incident rays increases with the obliquity of their incidence, and as the proportional loss is far smaller when the oblique rays pass into glass from water than when they enter it from air, the advantage of increasing the angular aperture is more fully experienced with "immersion" than with "dry" objectives,—just as Professor Amici anticipated. But, further, the immersion system allows of a greater working distance between the objective and the object than can be attained with a dry or air objective having the same angular aperture; and this increase affords not only a greater freedom of manipulation, but also a greater range of "penetration" or "focal depth." Further, the observer is rendered so much less dependent upon the exactness of his cover-correction that it is found that water-immersion objectives of high power and considerable angular aperture, extremely well adapted for the ordinary purposes of scientific investigation, can be constructed without it,—a small departure from the standard thickness of covering-glass to which such objectives are adjusted by the maker having scarcely any effect upon the distinctness of the image. It is now the practice of several makers to supply two fronts to objectives of $\frac{1}{10}$ or $\frac{1}{12}$ inch focus, one of them fitting the objective for use "dry" (that is, in air), whilst the substitution of the other converts it into a water-immersion objective. And in the objectives constructed on Mr Wenham's system no change in the front glass is needed, all that is necessary for making them work as immersion-lenses being a yet closer approximation of the front lens to the second combination, which can be made by the screw-collar.

Within the last few years, however, the immersion system has undergone a still further and most important development, by the adoption of a method originally suggested by Mr Wenham (though never carried out by him), and independently suggested by Mr Stephenson to Professor Abbe of Jena, under whose direction it was first worked out by Zeiss (the very able optician of Jena), who has been followed by Powell and Lealand of London, as well as by several other constructors of achromatic objec-

[1] *Trans. Soc. Arts*, vol. li.

tives both in England and elsewhere, with complete success. This method consists in the replacement of the water previously interposed between the covering-glass and the front glass of the objective by a liquid having the same refractive and dispersive powers as crown-glass, so that the rays issuing at any angle from the upper plane surface of the covering-glass shall enter the plane front of the objective, without any deflexion from their straight course, and without any sensible loss by reflexion,—even the most oblique rays that proceed from the object keeping their direction unchanged until they meet the back or convex surface of the front lens of the objective. It is obvious that all the advantages derivable from the system of water-immersion will be still more thoroughly attained by this system of "homogeneous" immersion, provided that a fluid can be obtained which meets its requirements. After a long course of experiments, Professor Abbe found that oil of cedar wood so nearly corresponds with crown-glass, alike in refractive and in dispersive power, as to serve the purpose extremely well, except when it is desired to take special advantage of the most divergent or marginal rays, oil of fennel being then preferable. There are, however, strong objections to the use of these essential oils in the ordinary work of research; and it seems not unlikely that a solution of some one or more saline substances will be found more suitable. In addition to the benefit conferred by the water-immersion system, and more completely attained with the homogeneous, it may be specially pointed out that, as no correction for the thickness of the covering-glass is here required, the microscopist can feel assured that he has such a view of his object as only the most perfect correction of an air-objective can afford. This is a matter of no small importance, for while, in looking at a known object, the practised microscopist can so adjust his air-objective to the thickness of its covering-glass as to bring out its best performance, he cannot be sure, in regard to an unknown object, what appearances it ought to present, and may be led by imperfect cover-correction to an erroneous conception of its structure.

It has been recently argued that, as the slightest variation in the refractive index of either the immersion fluid or the covering-glass, a change of eye-pieces, or the least alteration in the length of the body—in a word, any circumstances differing in the slightest degree from those under which the objective was corrected—must affect the performance of homogeneous-immersion objectives of the highest class, they should still be made adjustable. The truth of this contention can, no doubt, be proved, not only theoretically, but practically,—the introduction of the adjustment enabling an experienced manipulator to attain the highest degree of perfection in the exhibition of many mounted objects, which cannot be so well shown with objectives in fixed settings. But it may well be questioned whether it is likely to do the same service in the hands of an ordinary working histologist, and whether the scientific investigator will not find it preferable, when using these objectives, to accept what their maker has fixed as their point of best performance. The principal source of error in his employment of them lies in the thickness of the optical section of the object; for the rays proceeding from its deeper plane, having to pass through a medium intervening between that plane and the cover-glass, whose refractive and dispersive indices differ from those of the glass and immersion-fluid, cannot be brought to so accurate a focus as those proceeding from the plane immediately beneath the cover-glass. The remedy for this, however, seems to lie rather in making the preparation as thin as possible than in the introduction of what is likely, in any but the most skilful and experienced hands, to prove a new source of error. Every one who has examined muscular fibre, for example, under a dry objective of very high power and large aperture, well knows that so great an alteration is produced in its aspect by the slightest change in either the focal adjustment or the cover-correction that it is impossible to say with certainty what are the appearances which give the most correct optical expression of its structure. This being a matter of judgment on the part of each observer, it seems obvious that the nearest approach to a correct view will be probably given by the focal adjustment of the best homogeneous immersion-objectives, in fixed settings, to the plane of the preparation immediately beneath the cover-glass (see *Jour. Roy. Micros. Soc.*, 1882, pp. 407, 854, 906).

In every particular in which the water-immersion system is superior to the dry, it is itself surpassed by the oil or other homogeneous system, the anticipations of those by whom it was suggested being thus fully realized. But the advantages already spoken of as derivable from the use of the "immersion system" are altogether surpassed by that which the theoretical studies of Professor Abbe have led him to assign to it, and of which he has practically demonstrated its possession. For he has shown (as will be explained below) that the interposition of either water or oil so greatly increases the real "aperture" of the objective that immersion-objectives may be constructed having a far greater virtual aperture than even the theoretical maximum (180°) of the angular aperture of an air-objective.

The same eminent physicist, working on the basis supplied by the mathematical investigations of Professor Helmholtz and himself on the undulatory theory of light, has further established an entirely new doctrine in regard to the production of highly magnified representations of closely approximated markings. All that has hitherto been said of the formation of images by the compound microscope relates to such as are produced, in accordance with the laws of refraction, by the alteration in direction which the light-rays undergo in their passage through the lenses interposed between the object and the eye. These dioptric images, when formed by lenses free from spherical and chromatic aberration, are geometrically correct pictures, truly representing the appearances which the objects themselves would present were they enlarged to the same scale and viewed under similar illumination. And we seem justified, therefore, in drawing from such microscopic images the same conclusions in regard to the objects they picture as we should draw from the direct vision of actual objects having the same dimensions. The principal source of error in such interpretations arises out of the "interference" to which the rays of light are subjected along the edges of the minute objects through which they pass, or along any such lines or margins in their inner part as are sufficiently opaque to throw a definite shadow. For every such shadow must be bordered, more or less obviously, by interference- or diffraction-spectra; and thus the images of strongly-lined objects with very transparent intermediate spaces may be so troubled or confused by these "diffraction-spectra" as to render it very doubtful what interpretation is to be put upon their appearances.

A good example of this kind is afforded by the scales of the gnat or mosquito, which are composed of a very delicate double membrane, strengthened by longitudinal ribs on both sides, those of the opposite sides uniting at the broad end of the scale, where they generally terminate as bristle-shaped appendages beyond the intermediate membrane. These are crossed by fine markings, which are probably ridge-like corrugations of the membrane, common to both sides of the scale. Between each pair of longitudinal ridges there may be seen, under certain adjustments of focus and illumination, three uniform parallel rows of beads, which have been supposed to represent a true structure in the membrane. By Dr Woodward (colonel in the United States army), however, it has been shown that this beaded appearance is merely the result of the "interferences" produced by the longitudinal and transverse lines of the scale. For the longitudinal diffraction-lines are clearly seen, alike in the microscopic image and in photographs (fig. 13), to extend into empty space beyond the contour of the scales, almost as far as the ends of the bristles in which the parallel ribs terminate; and they vary in number with the varying obliquity of illumination, so that in the same scale two, three, four, or even five rows of beads can be seen, and photographed at pleasure, in every intercostal space.[1]

Every microscopist who has worked much with high powers is well aware of the difficulty of distinguishing between real and spectral markings,—a difficulty which can only be overcome by training and experience. It seems,

[1] *Monthly Micros. Jour.*, vol. xv. (1876), p. 253.

however, to have been now fully ascertained by Professor Abbe that it is only through such diffraction-spectra that the microscope can make us acquainted with the minutest structural features of objects, since, according to the calculations of Professor Helmholtz and himself (based on the constants of the undulatory theory), no amount of magnifying power can separate dioptrically two lines, apertures, or markings of any kind, not more than $\frac{1}{2600}$ of an inch apart. The visual differentiation or "resolution" of lines or other markings whose distance lies

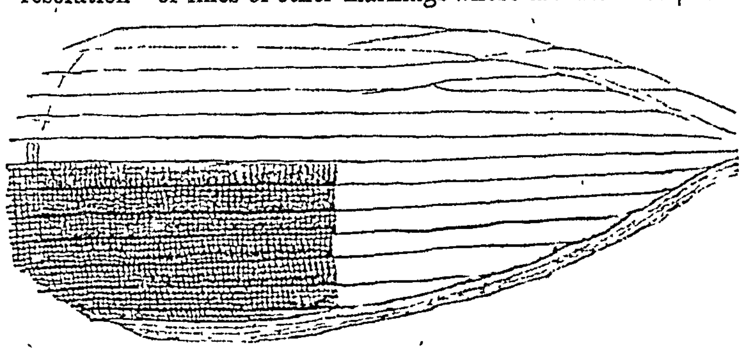


FIG. 13.—Scale of Gnat, showing Beaded Markings produced by Diffraction; from a Photograph by Colonel Dr Woodward.

within that limit is entirely the result of "interference,"—the objective receiving and transmitting, not only dioptric rays, but the inflected rays whose course has been altered in their passage through the object by the peculiar disposition of its particles, and combining these rays into a series of diffraction-spectra, the number and relative position of which bear a relation to the structural arrangement on which their production depends. If the objective be perfectly corrected, and all the diffraction-spectra lie within its field, these will be recombined by the eye-piece so as to form a secondary or "diffraction" image, lying in the same plane with the dioptric image, and coinciding with it, while filling up its outlines by supplying intermediate details. But where the markings (of whatever nature) are so closely approximated as to produce a wide dispersion of the interference-spectra, only a part of them may fall within the range of the objective; and the recombination of these by the eye-piece may produce a diffraction-image differing more or less completely (perhaps even totally) from the real structure; while, if they should lie entirely outside the field of the objective, no secondary or diffraction image will be produced. And thus, while the general form of such an object as a diatom-valve may be correctly given in a dioptric image, its surface may appear quite unmarked under an objective of small aperture, however great its magnifying power, though covered with regularly disposed markings when seen through an objective of wider aperture with perhaps only half the magnifying power.

It is obvious, however, that, while the dioptric image represents the actual object, the diffraction-image thus formed by the reunion of a portion of the interference pencils is only an optical expression of the result of their partial recombination, which may represent something entirely different from the real structure. For it has been proved experimentally, by placing finely-ruled gratings in the position of objects, and by limiting the apertures of objectives by diaphragms with variously disposed perforations, that the same arrangement of lines shall be presented to the eye by differently lined surfaces, and different arrangements by similarly lined surfaces, according to the numbers and relative positions of the reunited spectra. Hence it is clear that there must be an essential difference in character and trustworthiness between the images dioptrically formed of the general outlines and larger details of microscopic objects and those representations of their finer details which are given by the recombination of their diffraction-spectra,[1] and that the confidence to be placed in the latter class of representations will be greater in proportion to the completeness of the recombination of the separated interference-spectra, which, again, will be proportional (accurate correction of the aberrations being assumed) to the aperture of the objective.[2]

The combined advance of scientific theory and of practical skill in the application of it have now brought up the compound achromatic microscope to an optical perfection that renders it capable of actually doing almost everything of which, in the present state of optical theory, it can be regarded as capable. The resolution of Nobert's nineteenth band, having 112,595 lines to an inch, which was long regarded as the *crux* of microscopists, is now found so easy as to leave little room for doubt that, if a new test were obtainable having the *minimum visibile* of 118,000 lines to the inch, an oil-immersion objective would be found to resolve it. But the experience of the past makes it evident that, as no limit can be set to the advance of optical theory, results yet more remarkable may be still expected to arise, every such advance being turned to account by the practical skill which experience has now enabled the best constructors of achromatic objectives to attain.[3]

The progressive improvements thus effected in the construction of microscopic objectives have been accompanied by other improvements, alike in the optical and in the mechanical arrangements by which the best performance of these objectives can be secured; and it will be desirable now to describe in succession the most approved forms of the eye-piece, the objective, and the illuminating apparatus respectively, and then those of the instrument as a whole, pointing out the special adaptiveness of each to the requirements of different classes of scientific investigators.

Eye-Pieces.

It very early became obvious to those who were engaged in the achromatization of microscopic objectives that their best performance was obtained when the image given by them was further enlarged by the eye-piece known as the Huygenian, as having been devised by Huygens for his telescopes. It consists of two plano-convex lenses (EE and FF, fig. 4), with their plane sides towards the eye; these are placed at a distance equal to half the sum of their focal lengths,—or, to speak with more precision, at half the sum of the focal length of the eye-glass, and of the distance from the field-glass at which an image of the object-glass would be formed by it. A "stop" or diaphragm BB must be placed between the two lenses, in the visual focus of the eye-glass, which is, of course, the position wherein the image of the object will be formed by the rays brought into convergence by their passage through the field-glass. Huygens devised this arrangement merely to diminish the spherical aberration; but it was subsequently shown by Boscovich that the chromatic dispersion was also in great part corrected by it. Since the introduction of achromatic object-glasses for compound microscopes, it has been further shown that nearly all error may be avoided by a slight over-correction of these, so that the blue and red rays may be caused to enter the eye in a parallel direction (though not actually coincident), and thus to produce a colourless image. Thus let N, M, N (fig. 14) represent the two extreme rays of three pencils, which without the field-glass would form a blue image convex to the eye-glass at BB, and a red one at RR; then, by the intervention of the field-glass, a blue image concave to the eye-glass is formed at B'B', and a red

[1] Thus it is still a moot point whether the microscopic appearances seen in the siliceous valves of diatoms (figs. 8–11) are the optical representations of elevations, depressions, or perforations, or of internal molecular arrangements not involving any inequality of surface.

[2] This doctrine was first fully developed by Professor Abbe in the *Archiv für Mikrosk. Anatomie*, vol. ix. (1874), and is more fully expounded in his subsequent contributions to *Jour. Roy. Micros. Soc.* See also the papers of Mr Stephenson and Mr Crisp in that journal, and in the preceding *Monthly Microscopical Journal*.

[3] Any good workman can now make by the dozen such small-angled $\frac{1}{4}$ inch objectives as Mr A. Ross produced with much pains and labour fifty years ago. It was not until 1844 that, with the honourable emulation of surpassing what Professor Amici had then accomplished, he produced a $\frac{1}{12}$ inch of 135°, which, by taking advantage of some very heavy flint-glass he had, he afterwards increased to 170°.

one at R′R′. As the focus of the eye-glass is shorter for blue rays than for red rays by just the difference in the place of these images, their rays, after refraction by it, enter the eye in a parallel direction, and produce a picture free from false colour. If the object-glass had been rendered perfectly achromatic, the blue rays, after passing through the field-glass, would have been brought to a focus at *b*, and the red at *r*; so that an error would be produced, which would have been increased instead of being corrected by the eye-glass. Another advantage of a well-constructed Huygenian eye-piece is that the image produced by the meeting of the rays after passing through the field-glass is by it rendered concave towards the eye-glass instead of convex, so that every part of it may be in focus at the same time, and the field of view thereby rendered flat.[1]

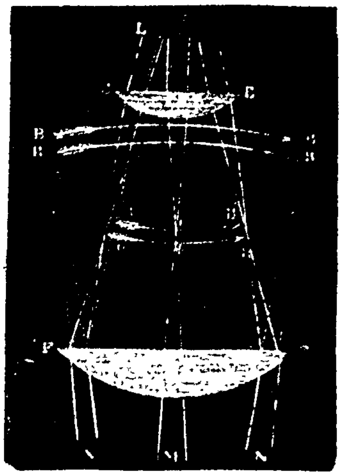


FIG. 14.—Section of Huygenian Eye-Piece, adapted to Over-Corrected Microscopic Objectives.

Two or more Huygenian eye-pieces, of different magnifying powers, known as A, B, C, &c., are usually supplied with a compound microscope. The utility of the higher powers will mainly depend upon the excellence of the objectives; for, when an achromatic combination of small aperture which is sufficiently well corrected to perform very tolerably with a "low" or "shallow" eye-piece is used with an eye-piece of higher magnifying power (commonly spoken of as a "deeper" one), the image may lose more in brightness and in definition than is gained by its amplification, while the image given by an objective of large angular aperture and very perfect correction shall sustain so little loss of light or of definition by "deep eye-piecing" that the increase of magnifying power shall be almost clear gain. Hence the modes in which different objectives of the same power, whose performance with shallow eye-pieces is nearly the same, are respectively affected by deep eye-pieces afford a good test of their respective merits, since any defect in the corrections is sure to be brought out by the higher amplification of the image, while a deficiency of aperture is manifested by the want of light. The working microscopist will generally find the A eye-piece most suitable, B being occasionally employed when a greater power is required to separate details, whilst C and others still deeper are useful for the purpose of testing the goodness of objectives, or for special investigations requiring the highest amplification with objectives of the finest quality. But he can commit no greater error than habitually to use deep eye-pieces for the purposes of scientific research, especially when (as in the study of living objects) long-continued and unintermitted observation is necessary. For the visual strain thus occasioned is exactly like that resulting from the habitual use of magnifying spectacles in reading, requiring the book to be held within 2 or 3 inches of the eye. And all experience shows that this feeling of strain cannot be disregarded, without the most injurious consequences to vision.

For viewing large flat objects, such as transverse sections of wood or of *Echinus* spines, under low magnifying powers, the eye-piece known as Kellner's may be employed with advantage. In this construction the field-glass, which is a double-convex lens, is placed in the focus of the eye-glass, without the interposition of a diaphragm; and the eye-glass is an achromatic combination of a plano-concave of flint with a double-convex of crown, which is slightly under-corrected, so as to neutralize the over-correction given to the objectives for use with Huygenian eye-pieces. A flat well-illuminated field of as much as 14 inches in diameter may thus be obtained, with very little loss of light; but, on the other hand, there is a certain impairment of defining power, which renders the Kellner eye-piece unsuitable for objects presenting minute structural details; and it is an additional objection that the smallest speck or smear upon the surface of the field-glass is made so unpleasantly obvious that the most careful cleansing of that surface is required every time that this eye-piece is used. Hence it is better fitted for the occasional display of objects of the character already specified than for the ordinary wants of the working microscopist.

Solid eye-pieces, consisting of cylinders of glass with convex ends, are sometimes used in place of the Huygenian, when high magnifying power is required for testing the performance of objectives. The lower surface, which has the lesser convexity, serves as a field-glass, while the image formed by this is magnified by the highly convex upper surface to which the eye is applied,—the advantage derivable from this construction lying in the abolition of the plane surfaces of the two lenses of the ordinary eye-piece.[2]

A "positive" or Ramsden's eye-piece—in which the field-glass, whose convex side is turned upwards, is placed so much nearer the eye-glass that the image formed by the objective lies below instead of above it—was formerly used for the purpose of micrometry,—a divided glass being fitted in the exact plane occupied by the image, so that its scale and that image are both magnified together by the lenses interposed between them and the eye. The same end, however, may be so readily attained with the Huygenian eye-piece that no essential advantage is gained by the use of that of Ramsden, the field of which is distinct only in its centre.

OBJECTIVES.

It has been seen that one of the principal points in the construction of microscopic objectives to which the attention of their makers has been constantly directed has been the enlargement of their "aperture,"—this term being understood to mean, not their absolute opening as expressed by linear measure, but their capacity for receiving and bringing to a remote conjugate focus the rays diverging from the several points of a near object. The aperture of an objective has been usually estimated by its "angle of aperture,"—that is, by the degree of divergence of the most extreme rays proceeding from the axial point of the object to the margin of the objective (fig. 15) which take part in the formation of the image. It is pointed out, however, by Professor Abbe that, in the case of single lenses used as objectives, their apertures are really proportional, not to their respective angles of aperture, but to the ratio between the actual diameter or clear opening of each to its focal distance, a ratio which is simply expressed by the sine of its semiangle. And in the case of combinations of lenses it can be demonstrated mathematically that their respective apertures are determinable—other conditions being the same—by the ratio of the diameters of their back lenses, so far as these are really utilized, to their respective focal lengths,—this ratio being expressed, as before, by the sine of the semiangle of aperture (sin u).

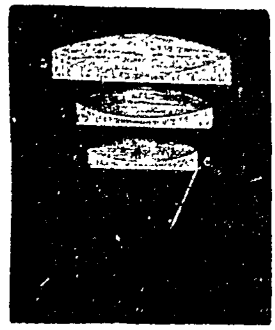


FIG. 15.—Section of Achromatic Object-Glass, composed of three pairs of (flint and crown) lenses. *abc* is its angle of aperture.

The difference between these two modes of comparison can be readily made obvious by reference to the theoretical maximum of 180°, which is attained by opening out the boundaries of the angle *abc* (fig. 15) until they come into the same straight line, the sine of the semiangle (90°) then becoming unity. For, while an objective having an angle of 60° would count by comparison of angles as having only one-third of the theoretical maximum, its real aperture would be half that maximum since the sine of its semiangle (30°) = ½. And, as the sines of angles beyond 60° increase very slowly, an objective of 120° angle will have as much as 87 per cent. of the theoretical maximum of aperture, although its angle is only two-thirds, or 66·6 per cent., of 180°. It hence becomes obvious that little is really gained in real aperture by the opening-out of the angle of microscopic objectives to its greatest practicable limit (which may be taken as 170°), while such extension—even if unattended with any loss either of definition or of colour-correction—necessarily involves a great reduction alike in the working distance and in the focal depth or penetration of the combination, as will be presently explained.

Numerical Aperture.—It has now been demonstrated by Professor Abbe that, independently of the advantages already specified as derivable from the application of the immersion system to objectives of short focus and wide aperture, the real aperture of an immersion objective is considerably greater than that of a dry or air objective of the same angle,—the comparative apertures of objectives working through different media being in the compound ratio of two factors, viz., the sines of their respective semiangles of aperture and the refractive indices of the "immersion" fluids. It is the product of these ($n \sin u$) that gives what is termed by Professor Abbe the "numerical aperture,"—which serves, therefore, as the only true standard of comparison, not only between dry or air and water or oil immersion lenses, but also between immersion lenses adapted to work respectively with water, oil, or any other interposed fluid. That the angle of aperture expressed by the same number of degrees must correspond with very different working apertures in dry, water immersion, and oil or homogeneous immersion objectives becomes evident when we consider what

[1] The reader may be referred to Mr Varley's investigation of the properties of the Huygenian eye-piece in the fifty-first volume of the *Transactions of the Society of Arts*; and to the article "Microscope," by Mr Ross, in the *Penny Cyclopædia*, reprinted, with additions, in the *English Cyclopædia*.

[2] These eye-pieces are much in vogue in the United States, where they are made of extremely short foci,—even to $\frac{1}{16}$ inch.

happens when divergent pencils of rays pass from one medium into another of higher refractive index. For such divergent pencils, proceeding from air into water or oil, will be closed together or compressed; so that the rays which, when an object is mounted in air, spread out over the whole hemisphere then form comparatively narrow pencils, and can thus be utilized by an immersion objective of smaller aperture than is required in a dry objective to admit the most diverging rays of air-pencils. It follows, therefore, that a given angle in a water or oil immersion objective represents a much larger aperture than does the same angle in an air-objective; and thus it comes to pass that by opening out the angle of immersion objectives they may be made to receive and utilize rays of much greater divergence than can possibly enter dry objectives of even maximum aperture.

The following table, abridged from that given by Professor Abbe for every 0·02 of numerical aperture from 0·50 up to the maximum of 1·52, brings this contrast into clear view:—

Numerical Aperture Table.

Numerical Aperture ($n \sin u = a$).	Angle of Aperture ($=2u$).			Illuminating Power (a^2).	Theoretical Resolving Power, in Lines to an Inch ($\lambda=0·5269\,\mu$ =line E).	Penetrating Power $\left(\frac{1}{a}\right)$.
	Dry Objectives ($n=1$).	Water-Immersion Objectives ($n=1·33$).	Homogeneous-Immersion Objectives ($n=1·52$).			
	° ′	° ′	° ′			
1·52	...	...	180 0	2·310	146,528	·658
1·42	...	...	138 12	2·016	136,888	·704
1·33	...	180 0	122 6	1·770	128,212	·752
1·26	...	142 39	111 59	1·588	121,464	·794
1·18	...	125 3	101 50	1·392	113,752	·847
1·12	...	114 44	94 56	1·254	107,968	·893
1·06	...	105 42	88 26	1·124	102,184	·943
1·00	180 0	97 31	82 17	1·000	96,400	1·000
0·94	140 6	89 56	76 24	·884	90,616	1 064
0·86	118 38	80 34	68 54	·740	82,904	1·163
0·80	106 16	73 58	63 31	·640	77,120	1·250
0·76	98 56	69 42	60 0	·578	73,264	1·316
0·70	88 51	63 31	54 50	·490	67,480	1·429
0·62	76 38	55 34	48 9	·384	59,768	1·613
0·56	68 6	49 48	43 14	·314	53,984	1·786
0·50	60 0	41 10	38 24	·250	48,200	2·000

Thus, taking as a standard of comparison a dry objective of the maximum theoretical angle of 180°, whose numerical aperture is the sine of 90°, or 1·00, we find this standard equalled by a water-immersion objective whose angle of aperture is no more than 97½°, and by an oil or homogeneous immersion objective of only 82°,—the numerical apertures of these, obtained by multiplying the sines of their respective semiangles by the refractive index of water or of oil, being 1·00 in each case. Each, therefore, will have as great a power of receiving and utilizing divergent rays as any dry objective can even theoretically possess.

But, as the actual angle of either a water or an oil immersion objective can be opened out to the same extent as that of an air or dry objective, it follows that the aperture of the former can be augmented far beyond even the theoretical maximum of the latter. Thus the numerical aperture of a water-immersion lens of the maximum angle of 180° is 1·33, or one-third greater than that of an air-lens of the same angle; and this aperture would be given by an oil-immersion objective of only 122°. Again, the numerical aperture of an oil-immersion objective having the theoretical maximum angle of 180° would be 1·52, or more than one-half greater than that of an air-lens of the same angle. And the numerical apertures corresponding to angles of 170°, which have been actually attained in both cases, fall very little short of the proportions just given.

So, again, an oil-immersion objective whose angle of aperture is only 60° has as high a numerical aperture (0·76) as a water-immersion objective of 69½°, or as a dry objective of 99°; and a dry objective of 140° has no greater a numerical aperture (0·94) than a water-immersion of 90° or an oil-immersion of 76½°.

This important doctrine may be best made practically intelligible by a comparison of the relative diameters of the back lenses of dry with those of water and oil immersion objectives of the same power, from an "air-angle" of 60° to an "oil-angle" of 180°,—these diameters expressing, in each case, the opening between the extreme pencil-forming rays at their issue from the posterior surface of the combination, to meet in its conjugate focus for the formation of the image, the relation of which opening in each case to the focal length of the combination is the real measure of its aperture (fig. 16). Thus the dry objective of 60° angle (5 in fig. 16) has its air-angle represented by $\sin u = \frac{1}{2} = 0·50$ numerical aperture. The dry objective of 97° (4) has its air-angle represented by $\sin u = \frac{3}{4} = 0·75$ numerical aperture. And the dry objective having the (theoretical) angle of 180° (3) has its air-angle represented by $\sin u = 1·00$ numerical aperture,—this corresponding to 96° water-angle and 82° oil-angle. But the water-immersion lens having the (theoretical) angle of 180° (2) has its water-angle represented by $n \sin u = 1·33$ numerical aperture. And the oil-immersion lens having the (theoretical) angle of 180° (1) has its oil-angle represented by $n \sin u = 1·52$ "numerical aperture."[1] These theoretical apertures for water and oil immersion lenses having been found as nearly attainable in practice as the theoretical maximum for dry objectives, such lenses can utilize rays from objects mounted in balsam or other dense media, which are entirely lost for the image (since they do not exist physically) when the same object is in air or is observed through a film of air. And this loss cannot be compensated by an increase of illumination; because the rays which are lost are different rays physically from those obtained by any illumination, however intense, through an aeriform medium.

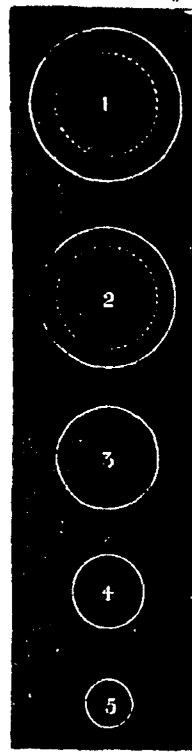


Fig. 16.—Relative Diameters of Back Lenses of Air, Water, and Oil Immersion Objectives.

It is by increasing the number of diffraction-spectra that the additional rays thus received by objectives of great numerical aperture impart to them an increased resolving power for lined and dotted objects,—the truth of the image formed by the recombination of these spectra being (as already shown) essentially dependent on the number of them that the objective may be capable of receiving.

But whilst the resolving power of microscopic objectives increases in the ratio of their respective numerical apertures, and whilst their illuminating power (dependent upon the quantity of light that passes through them) increases with the square of the numerical aperture, the case is reversed with another most important quality,—that of penetration or focal depth; for this diminishes as the numerical aperture increases, until nothing but what is precisely in the focal plane can be even discerned with objectives possessed of the highest resolving power. Thus, the penetrating power of an objective of 60° air-angle being expressed as 2·000, an extension of that angle to 76½° reduces it to 1·613, an extension to 89° reduces it to 1·429, and an extension to 99° reduces it to 1·316; further extension to 118½° reduces it to 1·163, while an objective whose air-angle is 140° has a penetrating power of only 1·064. So, again, the oil-immersion objective which has the numerical aperture of 1·00 corresponding to the theoretical air-angle of 180° has a penetrating power of 1·000; this is brought down to ·752 when its angle is so increased as to make its numerical aperture 1·33, equalling the theoretical maximum of a water-immersion objective, and is ·658 at the theoretical maximum (1·52) of an oil-objective.

Hence it is clear that, as some of the qualities to be sought in microscopic objectives are absolutely incompatible, a preference is to be accorded to objectives of greatest resolving power but very little penetration, or to those of moderate resolving power and great penetration, according to the uses to which they are to be applied; and some general principles will now be laid down in regard to this matter, based alike on science and experience.

In the first place, a marked distinction is to be drawn between those objectives of low or moderate power which are to be worked dioptrically and those of high power which are to be worked diffractively. The objects on which the former are to be for the most part used are either minute transparent bodies having solid forms which the observer should be able to take in as wholes (as in the case of *Polycystina*, the larger diatoms, *Infusoria*, &c.); or transparent sections, dissections, or injections, whose parts lie in different planes, the general relations of which he desires to study, while reserving their details for more special scrutiny; or opaque objects, whose structure can only be apprehended from the examination of their surfaces, when the inequalities of those surfaces are seen in their relations to each other. In all these cases it is desirable that microscopic vision should resemble ordinary vision as much as possible. If the eye were so constructed as to enable us to discern only those parts of an object that lie precisely in the plane to which we focus it, our visual conceptions of the forms and relations of these parts, and consequently of the object as a whole, would in general be very inadequate, and often erroneous. It is because, while focussing our eye successively on the several planes of the object, we can see the relation of each to what is nearer and more remote that we can readily acquire a visual conception of its shape as a whole, and that unmistakable perception of solid form which is given by the combination of the two dissimilar perspectives of near objects in binocular vision

[1] The dotted circles in the interior of 1 and 2, of the same diameter as 3, show the excess in the diameters of the back lenses of the water and oil objectives over that of the dry at their respective theoretical limits.

(p. 273) could not possibly be formed if our vision were strictly limited to the exact plane for which our eyes are focussed.

Hence it is obvious that, in the case of objectives of low and moderate amplification, focal depth or penetration is a quality for the want of which no other excellence can compensate,—the opening-out of their apertures being only advantageous in so far as it does not seriously interfere with their penetrating power. It is, no doubt, quite possible to construct a 1 inch objective with an aperture so large that, when the requisite amplification has been gained by deep eye-piecing, it shall resolve the lined "tests" ordinarily used for a ¼, or to construct an objective of 4/10 inch focus which shall in like manner do the ordinary work of a ⅛. But, as such objectives are thereby spoiled for their own proper work, the loss to the microscopist is but poorly compensated by his ability to resolve with them, under such deep eye-pieces as cannot be habitually used without serious risk to the eye-sight, the lined and dotted tests which can be much better shown under objectives of shorter focus and wider aperture, with eye-pieces of low amplification. For, whilst deep eye-pieces cannot be habitually employed for continuous observation, without putting a strain upon the eyes resembling that which results from the constant use of a magnifying glass, even the very highest objectives may be used continuously for long periods in combination with shallow eye-pieces, with scarcely any fatigue, and therefore (it is probable) without sensible injury.[1]

In estimating the goodness of a microscopic objective, five distinct qualities have to be separately considered:—(1) its working distance, or the actual interval between its front lens and the object on which it is focussed; (2) its penetrating power, or focal depth; (3) the flatness of its field; (4) its definition, or power of giving a distinct image of all well-marked features of an object, and especially of their boundary lines; and (5) its resolving power, by which it separates closely approximated lines, dots, or striæ.

1. The "working distance" of an objective has no fixed relation to its focal length,—the latter being estimated by its equality in power with a single lens of given radius of curvature (such as 1 inch, ¼ inch, 1/12 inch, &c.), while the former varies with the mode in which the combination is constructed and with the aperture given to it. For low and moderate powers, ranging up to 4/10 inch focus, good working distance is especially important, alike because it is closely related to penetrating power, and also because it facilitates the use of side-illumination for opaque objects. And in such objectives of high power as are to be used, not for the resolution of lined or dotted tests, but for the observation of living and moving objects of extreme minuteness, good working distance is no less important, on account of its relation to focal depth. In the case of those objectives, on the other hand, in which resolving power is made the first consideration, it is only needful that the working distance shall be such as to permit the interposition of a thin glass cover; and this, although necessarily diminished with the widening of the aperture, can be always obtained by the adoption of the immersion system.

2. The "penetrating power" or "focal depth" of an objective may be defined as consisting in the vertical range through which the parts of an object not precisely in the focal plane may be seen with sufficient distinctness to enable their relations with what lies exactly in that plane to be clearly traced out,—just as would be done by ordinary vision if the object were itself enlarged to the dimensions of its microscopic image. The close relation between this quality and the preceding becomes obvious when it is considered that the longer the working distance of an objective the less will the distinctness of the image it forms be affected by any given alteration (say the 1/10000 of an inch) in its focal adjustment. Consequently, of two objectives having the same magnifying power but different working distances, that one will have the most focal depth whose working distance is the greater. On the other hand, as the penetrating power of an objective is reduced in direct accordance with the increase of its numerical aperture, it must be sacrificed wherever the highest resolving power is to be attained. Hence, as already remarked, this attribute will be very differently valued by different observers, according to the work on which they are respectively engaged. For the general purposes of biological research, not only with low or moderate (for the reasons already stated), but also with high powers, a considerable amount of focal depth is essential. It is impossible, for example, to follow satisfactorily the movements of an *Amœba*, or to study the "cyclosis" in the cell of a *Vallisneria*, or to trace the distribution of a nerve-thread, with an objective in which focal depth is so completely sacrificed to aperture that nothing can be discerned save what is precisely in the focal plane, since, instead of passing gradationally from one focal plane to another, as the observer can do with an objective of good penetration, he can only get a succession of "dissolving views," with an interval of "chaos" between each pair. When, on the other hand, it is desired to scrutinize with the greatest precision such minute details as are presented in one and the same focal plane (as, for example, those of the thinnest possible film of tissue spread out between a glass slide and its covering glass), the microscopist will prefer an objective in which focal depth is subordinated to aperture, for the sake of the resolving power which he can thus command. And it will often happen in biological research that it is advantageous thus to bring objectives of the latter class to bear upon objects which could not have been detected in the first instance save by objectives of much inferior resolving power but greater focal depth.

[1] Hence, for work of this kind, the shallower eye-pieces and longer tubes of English microscopes are to be preferred to the deeper eye-pieces and shorter tubes of the ordinary Continental model, the shallowest eye-pieces of the latter being usually equal in power to the ordinary B eye-pieces of the former.

3. The "flatness of the field" afforded by the objective is a condition of great importance to the advantageous use of the microscope, since the extent of the area clearly seen at one time practically depends upon it. Many objectives are so constructed that, even when the object is perfectly flat, the foci of the central and peripheral parts of the field are so different that, when the adjustment is made for one, the other is more or less indistinct. Hence, when the central part of the area is in focus, no more information is gained respecting the peripheral than if the latter had been altogether stopped out. With a really good objective, not only should the image be distinct over the whole field at once, but the marginal portion should be as free from colour as the central. As imperfection in this respect is often masked by the contraction of the aperture of the diaphragm in the eye-piece, the relative merits of two objectives, as regards flatness of field, should always be tested under an eye-piece giving a large aperture.

4. The "defining power" of an objective, which depends upon the completeness of its corrections for spherical and for chromatic aberration, and upon the accurate centring of its component lenses, is an attribute essential to its satisfactory performance, whatever may be its other qualities,—its importance in scientific research being such that no superiority in resolving power can compensate for the want of it; and, though it is possible to obtain perfect correction for spherical aberration up to the highest practicable limit of angle, yet the difficulty of securing it increases rapidly with the augmentation of aperture, the want of it being made perceptible, especially when deep eye-pieces are put on, by the blurring of clearly-marked lines or edges, and by general "fog." Perfect colour-correction, on the other hand, is not possible for dry lenses of the widest angle, on account of the irrationality of the secondary spectrum; but this may be neutralized by the use of the immersion system. As already stated, what has to be aimed at in the construction of microscopic objectives is not absolute colour-correction, but a slight degree of over-correction, which, by compensating the chromatic dispersion of the Huygenian eye-piece, shall produce an image free from false colour. As this can be secured far more easily in the construction of objectives of moderate than in those of very wide aperture, the cost of the former is proportionally small,—an additional reason for the preference to be given to them on other grounds, in regard to all save very special kinds of microscopic work.

5. "Resolving power," being that by which very minute and closely approximated markings—whether lines, striæ, dots, or apertures—can be separately discerned, is a function which is only of primary importance in objectives whose amplifying power specially fits them for the study of objects of this class. It appears from the mathematical researches of Professor Abbe that the maximum resolving power (with a theoretical angle of 180°) would be capable of separating 146,528 lines to the inch; but he considers the limit of visual resolution depending on the power of the eye to be about 1/113000 of an inch; and this limit seems to have been nearly reached. To make such a separation distinctly perceptible, an amplification of at least 3000 linear would be requisite; and this can only be obtained either by the use of an objective of very high power (such as 1/25 inch focus) in combination with a low or medium eye-piece or by putting a very deep eye-piece upon an objective of lower power (such as a ⅛ inch),—the former method, for the reasons already given, being decidedly preferable. For the resolution of less closely approximated markings objectives of 1/20, 1/10, 1/12, and ⅛ inch answer very well; and the resolving power which they require may be obtained without any excessive widening of the aperture. For the loss of resolving power consequent upon the contraction of the angle of a water-immersion objective to 128⅓° is only one-tenth of the theoretical maximum 128,212; while a reduction to 105⅔° only lowers the number of separable lines to 102,184 to the inch,—thus diminishing the resolving power by little more than one-fifth, while the working distance and focal depth of the combination are greatly increased, and perfect definition is more certainly attainable. The ⅛ inch is (according to the writer's experience, which is confirmed by the theoretical deductions of Professor Abbe) the lowest objective in which resolving power should be made the primary qualification,—the ⅙, ⅕, ¼, and 4/10 inch being specially suited to kinds of biological work in which this is far less important than focal depth and dioptric precision. This view is strengthened by the very important consideration that the resolving power given by wide aperture cannot be utilized, except by a method of illumination that causes light to pass through

the object at an obliquity corresponding to that at which the most divergent rays enter the objective. Now, although in the case of objects whose markings are only superficial such obliquity may not be productive of false appearances (though even this is scarcely conceivable), it must have that effect when the object is thick enough to have an internal structure; and the experience of all biological observers who have carried out the most delicate and difficult investigations is in accord, not only as to the advantage of direct illumination, but as to the deceptiveness of the appearances given by oblique, and the consequent danger of error in any inferences drawn from the latter. Thus, for example, the admirable researches of Strassburger, Fleming, Klein, and others upon the changes which take place in cell-nuclei during their subdivision can only be followed and verified (as the writer can personally testify) by examination of these objects under axial illumination, with objectives of an angle so moderate as to possess focal depth enough to follow the wonderful differentiation of component parts brought out by staining processes through their whole thickness.

The most perfect objectives for the ordinary purposes of scientific research, therefore, will be obviously those which combine exact definition and flatness of field with the widest aperture that can be given without an inconvenient reduction of working distance and loss of the degree of focal depth suitable to the work on which they are respectively to be employed. These last attributes are especially needed in the study of living and moving objects; and, in the case of these, dry objectives are decidedly preferable to immersion, since the shifting of the slide which is requisite to enable the movement of the object to be followed is very apt to produce disarrangement of the interposed drop. And, owing to the solvent power which the essential oils employed for homogeneous immersion have for the ordinary cements and varnishes, such care is necessary in the use of objectives constructed to work with them as can only be given when the observer desires to make a very minute and critical examination of a securely-mounted object.

The following table expresses the magnifying powers of objectives constructed on the English scale of inches and parts of an inch, with the 10 inch body and the A and B eye-pieces usually supplied by English makers, and also specifies the angle of aperture which, in the writer's judgment, is most suitable for each. He has the satisfaction of finding that his opinions on this latter point, which are based on long experience in the microscopic study of a wider range of animal and vegetable objects than has fallen within the purview of most of his contemporaries, are in accordance with the conclusions drawn by Professor Abbe from his profound investigations into the theory of microscopic vision,[1] which have been carried into practical accomplishment in the excellent productions of Mr Zeiss.

Focal Length.	Angular Aperture.	Magnifying Power.		Focal Length.	Angular Aperture.	Magnifying Power.	
		A Eye-piece.	B Eye-piece.			A Eye-piece.	B Eye-piece.
	°				°		
4 inches	9	12	18	¼ inch.	50–80	200	300
3 „	12	18	27	⅕ „	95	250	375
2 „	15	25	37	⅙ „	110	300	450
1½ „	20	36	54	⅛ „	140	400	600
1 „	30	50	75	$\frac{1}{10}$ „	150	500	750
⅔ „	40	75	112	$\frac{1}{12}$ „	160	600	900
½ „	45	100	150	$\frac{1}{16}$ „	170	800	1200
$\frac{4}{10}$ „	70	125	187				

For ordinary biological work, the ⅕, $\frac{1}{10}$, and $\frac{1}{12}$ objectives, with angles of from 100° to 120°, will be found to answer extremely well if constructed on the water-immersion system.

Each of these powers should be tested upon objects most suited to determine its capacity for the particular kind of work on which it is to be employed; and, in such testing, the application of deeper eye-pieces than can be habitually employed with advantage will often serve to bring out marked differences between two objectives which seem to work almost equally well under those ordinarily used,—defects in definition or colour-correction, and want of light, which might otherwise have escaped notice, being thus made apparent. No single object is of such general utility for these purposes as a large well-marked *Podura* scale; for the eye which has been trained to the use of a particular specimen of it will soon learn to recognize by its means the qualities of any objective between 1 inch and ⅕ inch focus; and it may be safely asserted that the objective which most clearly and sharply exhibits its characteristic markings is the best for the ordinary work of the histologist.

For the special attribute of resolving power, on the other hand, tests of an entirely different order are required; and these are furnished, as already stated, either by the more "difficult" diatoms, or by the highest numbers of Nobert's ruled test-plate. The diatom-valve at present most in use as a test for resolving power is the *Amphipleura pellucida*, the lines on which were long supposed to be more closely approximated than those of Nobert's nineteenth band, being affirmed by Mr Sollitt to range from 120 to 130 in $\frac{1}{1000}$ of an inch. But the admirable photographs of this valve obtained by Colonel Dr Woodward have confirmed the conclusion long previously expressed by the writer, that this estimate was far too high, being based on the "spurious lineation" produced by diffraction, and show that the striæ on the largest valves do not exceed 91, while those on the smallest are never more numerous than 100, in $\frac{1}{1000}$ of an inch. The same admirable manipulator has also obtained excellent photographs of another very difficult test-diatom, *Surirella gemma*, from which it appears that its transverse striæ count longitudinally at the rate of 72,000 to the inch, whilst the beaded appearances into which these may be resolved count transversely at the rate of 84,000 to the inch. Thus it appears that the complete resolution of these "vexatious" diatoms does not require by any means the maximum of aperture, but is probably dependent at least as much on the perfection of the corrections and the effectiveness of the illumination.

It must be understood that there is no intention in these remarks to undervalue the efforts which have been perseveringly made by the ablest constructors of microscopic objectives in the direction of enlargement of aperture. For these efforts, besides increasing the resolving power of the instrument, have done the great service of producing a vast improvement in the quality of those objectives of moderate aperture which are most valuable to the scientific biologist; and the microscopist who wishes his *armamentum* to be complete will provide himself with objectives of those different qualities, as well as different powers, which shall best suit his particular requirements.[2]

Illuminating Apparatus.

Every improvement in the optical performance of the compound achromatic microscope has called forth a corresponding improvement in the illumination of the objects viewed by it, since it soon came to be apparent that without such improvement the full advantage of the increased defining and resolving powers of the objectives could not be obtained. For the illumination of transparent objects examined by light transmitted through them under low powers of moderate angle a converging pencil of rays reflected upon their under surface by a concave mirror is generally sufficient,—a "condenser" being only needed when the imperfect transparency of the object requires the transmission of more light through it. And the microscopist engaged in ordinary biological studies, who works on very transparent objects with objectives of ⅕ or ⅙ inch focus, or $\frac{1}{12}$ inch immersion, will find that the small concave mirror of short focus with which the Continental models are furnished (see fig. 28) will generally prove sufficient for his needs. This mirror is usually hung at such a distance beneath the stage that parallel rays falling on it are brought to a focus in the object as it lies on a slip of glass resting on the stage; and thus, when the instrument is used by day, the light of a bright cloud (which is preferable to any other) gives a well-illuminated field, even with the powers last-mentioned. But when lamplight is used its divergent rays are not brought to a focus in the object by a mirror that is fixed as just stated; and the distance of the mirror beneath the stage should be made capable of increase (which is easily done by attaching it to a lengthening bar), so as to obtain the requisite focal convergence. Still the best effects of objectives of less than ¼ inch focus cannot be secured without the aid of an achromatic condenser, interposed between the mirror and the object, so as to bring a larger body of rays to a more exact convergence.

When objectives of still higher power are employed, the employment of such a condenser becomes indispensable; and when the highest powers are being used by lamplight, it is desirable to dispense with the mirror altogether, and to place the flame exactly in the optic axis of the microscope. The condenser should be an achromatic combination, corrected for the ordinary thickness of the glass slip on which the object lies, and capable of being so adjusted as to focus the illuminating pencil in the object.

As it is often found desirable that an object should be illuminated by central rays alone, or that the quantity of light transmitted through it should be reduced (for bringing into view delicate details of structure which are invisible when the object is flooded with light), every microscope should be provided with some means of cutting off the outer rays of the illuminating cone. The "diaphragm-plate" ordinarily used for this purpose is a disk of black metal, pivoted to the under side of the stage, and perforated with a graduated series of apertures of different diameters, any one of which can be brought, by the rotation of the disk, exactly into the optic axis of the microscope. But the required effect can be much more advantageously obtained by the "iris-diaphragm," in which a number of converging plates of metal are made so to slide over each other by the motion of a lever or screw that the aperture is either enlarged or diminished, while always remaining practically circular as well as central; and in this manner a continuous

[1] See his paper on "The Relation of Aperture and Power in the Microscope," in *Jour. Roy. Micros. Soc.*, 1882, pp. 300, 460.

[2] See the remarks of Mr Dallinger,—whose experience in the application of the highest powers to the study of the minutest living objects is probably greater than that of any living observer,—in *Jour. Roy. Micros. Soc.*, December 1882, p. 853.

view of the object is obtained, with a gradational modification of the light. Another method, commonly adopted in German microscopes, is to place a draw-tube in the optic axis between the stage and the mirror, and to drop into the top of this tube one of a set of "stops" perforated with apertures of different sizes; this allows a gradational effect to be obtained by raising or lowering the tube, so as to place the stop nearer to or more remote from the object; but it is not nearly so convenient as the iris-diaphragm; and the effect of the stop is not nearly so good when it is removed to some distance beneath the object as when it is very near to the under surface of the glass object-slide. When an achromatic condenser is used, either a diaphragm-plate or an iris-diaphragm should be placed below its back lens, so as to cut off any required proportion of the outer rays that form its illuminating cone.

Such an arrangement, while suiting all the ordinary requirements of the microscopist who uses the highest powers of his instrument for the purposes of biological investigation (as, for example, in the study of *Bacteria* or of the reproduction of the *Monadina*), does not serve to bring into effective use the special resolving power possessed by objectives of large aperture. It has long been known that for the discernment of very closely approximated markings oblique illumination is advantageous,—an objective which exhibits such a diatom-valve as *Pleurosigma angulatum* with a smooth unmarked surface when illuminated by the central rays of the achromatic condenser making its characteristic markings (figs. 8–11) distinctly visible when the central rays of the condenser are kept back by a stop, and the object is illuminated by its convergent marginal rays only. And it has also been practically known for some time that the resolution of lined or dotted tests can be often effected by mirror illumination alone, if the mirror be so mounted as to be able to reflect rays through the object at such obliquity to the optic axis of the microscope as to reach the margin of a wide-angled objective. But it has only been since Professor Abbe's researches have given the true theory of "resolution" that the special advantage of oblique illumination has been fully comprehended, and that the best means have been devised for using it effectively. Two different systems have now come into use, each of which has its special advantages.

One consists in the attachment of the illuminating apparatus (mirror and achromatic condenser) to a "swinging tail-piece" (see fig. 32), which, moving radially upon a pivot whose axis intersects the optic axis at right angles in the plane of the object, can transmit the illuminating pencil through it at any degree of obliquity that the construction of the stage allows. The direction of this pencil being of course limited to one azimuth, it is requisite, in order to bring out its full resolving effect, that the object should be made to rotate, by making the stage that carries it revolve round the optic axis, so that the oblique pencil may impinge upon the lines or other markings of the object in every direction successively. It will then be found that the appearances presented by the same object often vary considerably,—one set of lines being shown when the object lies in one azimuth, and another when its azimuth has been changed by rotation through 60°, 90°, or some other angle. Various contrivances have also been devised for throwing very oblique illuminating pencils on the object by means of prisms placed beneath the stage.

Illumination of at least equal obliquity to that afforded by the swinging tail-piece may now, however, be obtained by the use of condensers specially constructed to give a divergence of 170° to the rays which they transmit when used immersionally, by bringing their flat tops into approximation to the under side of the glass slide on which the object is mounted, with the interposition of a film of water or (preferably) of glycerin. By using a central stop, marginal rays alone may be allowed to pass; and these will be transmitted through the object in every azimuth at the same time. But diaphragms with apertures limiting the transmitted rays to one part of the periphery may be so fixed in a tube beneath the condenser as to be easily made to rotate, thus sending its oblique pencils through the object in every azimuth in succession. And where this rotation of the diaphragm brings out two sets of lines at a certain angular interval a diaphragm with two marginal openings at a corresponding angular distance will enable both to be seen at once. Numerous arrangements of this kind have been devised by those who devote their special attention to the resolution of difficult diatom-tests; but they are of little or no use to those who use the microscope for biological research.

For the illumination of the surfaces of opaque objects which must be seen by reflected light the means employed will vary with the focal length of the objective employed. For large bright objects viewed under a low magnifying power good ordinary daylight is sufficient; but if the surface of the object is dull, reflecting but little light, the aid of a bull's-eye or large bi-convex lens must be employed in order to give it sufficient brilliance. This aid will always be required by lamplight; and by a proper adjustment of the relative distances of the lamp and the object the rays from the lamp may be made either to spread themselves over a wide area or to converge upon a small spot. The former is the method suitable to large objects viewed under a low magnifying power; the latter to the illumination of small objects which are to be examined under objectives of (say) 1 inch or ⅔ inch focus. Another method which may be conveniently had recourse to when the microscope is provided with a swinging tail-piece is to turn this on its pivot until the concave mirror is brought above the stage, so that rays which it gathers either from natural or artificial sources may be reflected downwards upon the surface of the object.

The illumination of an opaque object to be seen with a higher power than the ⅔ or ½ inch objectives was formerly provided for by a concave speculum (termed a Lieberkuhn after its inventor), with a perforation in the centre for the passage of the rays to the objective to which it is fitted,—the curvature of the speculum being so adapted to the focus of the objective which carries it that, when the latter is duly adjusted, the rays reflected upwards around the object from the mirror to the speculum shall converge strongly on the object. The various disadvantages of this mode of illumination, however, have caused it to be now generally superseded by other arrangements. For powers between 1½ inch and $\frac{1}{10}$ inch, and even for a ¼ or ⅕ inch of small angle and good working distance, nothing is so convenient as the parabolic speculum or side-illuminator (F, fig. 17) invented by the late Richard Beck. This is attached to a spring-clip that slides on the tubes of low-power objectives, so that its distance from the object and the direction of its reflected pencil are readily adjusted; and for use with higher powers it may be either mounted on a separate arm attached to some part of the stand of the microscope, or may be hung in the manner shown in fig. 17 from an "adapter" A interposed between the objective and the body. By rotating the collar B and making use of the joints C, C, the lengthening rod D, and the ball and socket E, any position may be given to the speculum F that may best suit the objective with which it is used.

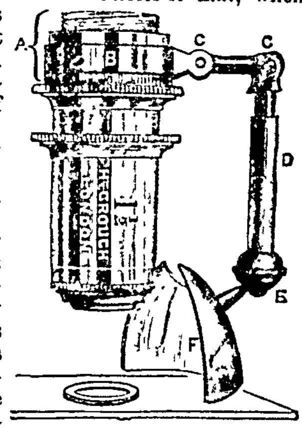


Fig 17.—Beck's Parabolic Side-Illuminator, with Crouch's Adapter.

When, however, it is desired to illuminate objects to be seen under objectives of high power and very short working distance, side illumination of any kind becomes difficult, though not absolutely impossible;[1] and various modes have been devised for the illumination of the object by means of light sent down upon it, through the objective, from above. This is done in the vertical illuminator of Messrs Beck (fig. 18)—the original idea of which was first given by the American Professor H. L. Smith—by a disk of thin glass B, *b*, attached to a milled head by which its angular position may be adjusted, and introduced by a slot A, *e* into the interior of an adapter that is interposed between the objective C, *d* and the nose *c* of the body. The light which enters at the lateral aperture A, *a*, falling upon the oblique surface of the disk C, *b*, is reflected downwards, and is concentrated by the lenses of the objective upon the object beneath. The lateral aperture may be provided with a diaphragm, with openings of different sizes, for diminishing the false light to which this method is liable; or a screen with a small aperture may be placed between the lamp and the

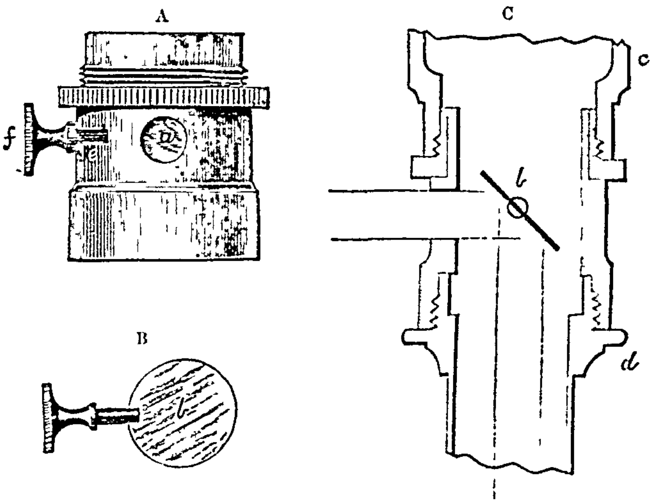


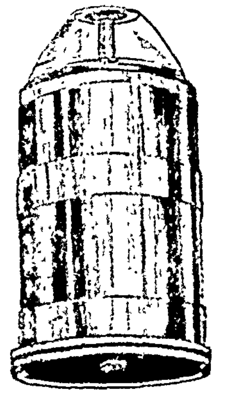
Fig. 18.—Beck's Vertical Illuminator.

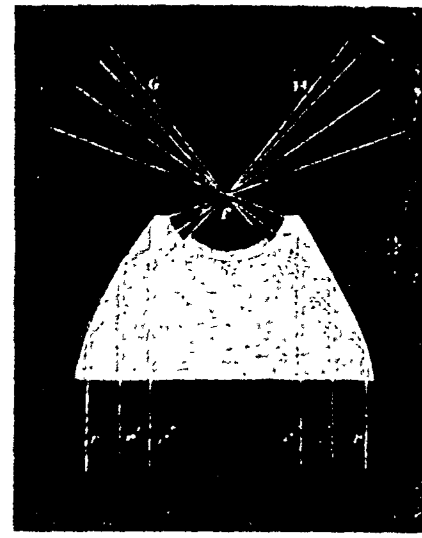
[1] See a method devised by Mr James Smith, in *Jour. R. Micr. Soc.*, vol. iii., N. S., 1880, p. 898.

illuminator, at any distance that is found to produce the best effects. In using this illuminator, the lamp should be placed at a distance of about 8 inches from the aperture; and, when the proper adjustments have been made, the image of the flame should be seen upon the object. The illumination of the entire field, or the direction of the light more or less to either side of it, can easily be managed by the interposition of a small condensing lens placed at about the distance of its own focus from the lamp. The objects viewed by this mode of illumination with dry-front objectives are best uncovered, since, if they are covered with thin glass, so large a proportion of the light sent down upon them is reflected from the cover (especially when objectives of large angle of aperture are employed) that very little is seen of the objects beneath, unless their reflective power is very high. With immersion objectives, however, covered objects may be used. Another method of vertical illumination long since devised by Mr Tolles has recently been brought into notice by Professor W. A. Rogers of Boston (U. S.). It consists in the introduction of a small rectangular prism at a short distance behind the front combination of the objective, so that parallel rays entering its vertical surface pass on between its parallel horizontal surfaces until they meet the inclined surface, by which they are reflected downwards. In passing through the front combination of the objective, they are deflected towards its axis; but, as their angle of convergence is less than the angle of divergence of the rays proceeding from the object, the reflected rays will not meet in the focal point of the lens, but will be so distributed as to illuminate a sufficient area. By altering the extent to which the prism is pushed in, or by lifting or depressing its outer end by means of a milled-head screw, the field of illumination can be regulated. The working of this prism with immersion-objectives is stated by Mr Tolles to be peculiarly satisfactory.

Black-Ground Illumination.—There are certain classes of objects which, though sufficiently transparent to be seen with light transmitted through them, are best viewed when illuminated by rays of such obliquity as not to pass directly into the objective,—such a proportion of these rays being retained by the object as to render it self-luminous, when, all direct light being cut off, the general field is perfectly dark. This method is particularly effective in the case of such delicate mineral structures as the siliceous tests of *Polycystina* and the "frustules" of *Diatomaceæ*. And it is one advantage of this kind of illumination that it brings out with considerable effect the solid forms of objects suited to it, even when they are viewed monocularly. Two modes of providing this illumination are in use, each of which has its special advantages. One consists in placing a central stop either upon or immediately beneath a condenser of wide aperture, which shall cut off all rays save those that, after passing through the object (as in fig. 20), diverge at an angle greater than that of the objective used; so that, while the ground is darkened, the object is seen brightly standing out upon it. But if the divergence of the rays is but moderate (say 60°), and the angle of the objective is large (say 90°), the most divergent rays of the condenser will enter the marginal portion of the objective, and, the field not being darkened, the black-ground effect will not be produced. This method has the great convenience of allowing black-ground illumination to be substituted for the ordinary illumination under different powers, without any other change in the apparatus than the turning of a diaphragm-plate fitted with stops of different sizes suitable to the several apertures of the objectives; and the modern achromatic condensers of wide aperture can be thus used with objectives of 120° angle.

An excellent black-ground illumination is also given by the parabolic illuminator (fig. 19), originally worked out as a silvered speculum by Mr Wenham, but now made as a paraboloid of glass that reflects to its focus the rays which fall upon its internal surface. A diagrammatic section of this instrument, showing the course of the rays through it, is given in fig. 20, the shaded portion representing the paraboloid. The parallel rays r, r', r'', entering its lower surface perpendicularly, pass on until they meet its parabolic surface, on which they fall at such an angle as to be totally reflected by it, and are all directed towards its focus F. The top of the paraboloid being ground out into a spherical curve of which F is the centre, the rays in emerging from it undergo no refraction, since each falls perpendicularly upon the part of the surface through which it passes. A stop placed at S prevents any of the rays reflected upwards by the mirror from passing to the object, which, being placed at F, is illuminated by the rays reflected into it from all sides of the paraboloid. Those rays which pass through it diverge again at various angles; and if the least of these, GFH, be greater than the angle of aperture of the object-glass, none of them can enter it. The stop is attached to a stem of wire, which passes vertically through the paraboloid and terminates in a knob beneath, as shown in fig. 19; and by means of this it may be pushed upwards, so as to cut off the less divergent rays in their passage towards the object, thus giving a black-ground illumination with objectives of an angle of aperture much wider than GFH. In using the paraboloid for delicate objects, the rays which are made to enter it should be parallel; consequently the plane mirror should always be employed; and when, instead of the parallel rays of daylight, we are obliged to use the diverging rays of a lamp, these should be rendered as parallel as possible, previously to their reflexion from the mirror, by the interposition of the "bull's-eye" so adjusted as to produce this effect. There are many cases, however,





Figs. 19, 20.—Wenham's Parabolic Illuminator.

in which the stronger light of the concave mirror is preferable. When it is desired that the light should fall on the object from one side only, the circular opening at the bottom of the wide tube that carries the paraboloid may be fitted with a diaphragm adapted to cover all but a certain portion of it; and, by giving rotation to this diaphragm, rays of great obliquity may be made to fall upon the object from every azimuth in succession.

In order to adapt this paraboloid to objectives of very wide angle of aperture, a special modification of it, originally devised by Mr Wenham, has been latterly reintroduced under the designation of "immersion-paraboloid," with most excellent effect. This consists in making the top of the paraboloid flat instead of concave, and in interposing a film of glycerin between its surface and the under surface of the glass slide carrying the object. Only rays of such extreme obliquity are allowed to pass into the slide as would be totally reflected from its under surface if they fell upon it through air; and, as these illuminate the object without passing into the objective, it can be thus examined under even the highest powers.

Binocular Microscopes.

Stereoscopic Binoculars.—The admirable invention of the stereoscope by Professor Wheatstone has led to a general appreciation of the value of the conjoint use of both eyes, in conveying to the mind a conception of the solid forms of objects such as the use of either eye singly does not generate with the like certainty or effectiveness (see Stereoscope). This conception is the product of the mental combination of the dissimilar perspective projections which our right and left retinæ receive of any object that is sufficiently near the eyes for the formation of two images that are sensibly dissimilar. Now it is obvious that a similar difference must exist between the two perspective projections of any object in relief that are formed by the right and left halves of a microscopic objective and that this difference must increase with the angular aperture of the objective. And the fact of this difference may be easily made apparent experimentally, by adapting a semicircular "stop" to any objective of from 20° to 30° angle in such a manner that it can be turned so as to cover either its right or its left half; for not only will the two images of any projecting object formed by the rays transmitted through the two uncovered halves be found sensibly different, but, if they be photographed or accurately drawn, the "pairing" of their pictures in the stereoscope will bring out the form of the object in vivid relief. What is needed, therefore, to give the true stereoscopic effect to a binocular microscope is a means of so bisecting the cone of rays transmitted by the objective that its two lateral halves shall be transmitted the one to the right and the other to the left eye, and that the two images shall be crossed (the image formed by the right half of the objective being sent to the left eye, and that formed by the left half of the objective being sent to the right eye) in order to neutralize the reversing effect of the microscope itself. If this crossing does not take place, the effect will be rendered "pseudoscopic," not "orthoscopic,"—its projections becoming depressions, and its depressions being brought out as prominences. It was from a want of due appreciation of this fact that the earlier attempts at constructing a stereoscopic binocular gave representations of objects placed under it, not in their true orthoscopic, but in their pseudoscopic aspect. This was the case, for example, with the binocular microscope first devised by

Professor Riddell of New Orleans in 1851, which separated the cone of rays by a pair of rectangular prisms so placed edge to edge above the objective that the rays passing through its right half were reflected horizontally to the right side, to be changed to the vertical direction and sent to the right eye by a lateral rectangular prism, while the rays from the left half of the objective were sent to the left eye in a similar manner. Professor Riddell describes the "conversion of relief" produced by this arrangement with the ordinary eye-piece as making a metal spherule appear "as a glass ball silvered on the under side, and a crystal of galena like an empty box." And to render the images "normal and natural" he found himself obliged to use erecting eye-pieces, which should produce a second reversal of the images that had been reversed in their first formation.[1] Subsequently, however, Professor Riddell devised and perfected another arrangement giving a true orthoscopic effect, which, after being long disregarded, has been latterly taken up and brought into use by Mr Stephenson. The cone of rays passing upwards from the objective meets a pair of prisms (A, A fig. 21) fixed immediately above its back lens, which divides it into two halves; each of these is subjected to internal reflexion from the inner side of the prism through which it passes; and the slight separation of the two prisms at their upper end gives to the two pencils B, B, on their emergence from the upper surfaces of the prisms, a divergence which directs them through two obliquely-placed bodies to their respective eye-pieces. By this internal reflexion a lateral reversal is produced, which neutralizes that of the ordinary microscopic image, so that, while each eye receives the image formed by its own half of the objective, the pairing of the two pictures produces a true orthoscopic effect.[2]

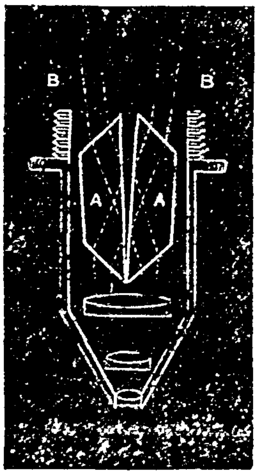


Fig. 21.—Riddell's Binocular Prisms.

About the same date MM. Nachet of Paris succeeded in devising a binocular that should give a true orthoscopic image, by placing above the object-glass an equiangular prism (P. fig. 22) with one of its surfaces parallel to its back lens, which, receiving the pencils *ab* forming the right half of the cone, internally reflects them obliquely upwards to the left, and in like manner reflects the pencils *a'b'* from the left half of the cone obliquely upwards to the right. These pencils, passing out of the left and right oblique faces of the prism at right angles (so as not to undergo either refraction or dispersion), enter right and left lateral prisms, also at right angles, and, after being internally reflected by these, pass out vertically, at right angles to their upper surfaces, through two parallel bodies (fig. 23), whose eye-pieces bring them to a focus in the right and left eyes respectively. The distance between these bodies may be adjusted to the varying distances between the axes of individual pairs of eyes, by adjusting screws at their base, which vary the distance of the lateral prisms from the central. This instrument gives a theoretically perfect representation of a microscopic object in relief, as it would appear if enlarged to the size of its image, and brought to within about 10 inches of the eye; and its chief practical defect is that, as the two bodies are parallel, instead of being slightly convergent, it cannot be continuously used without an uncomfortable strain. But, as its performance depends upon the accuracy of the seven plane surfaces of the three prisms, and on the correctness of their relations to each other, it is liable to considerable error from imperfections in its construction; and, as the instrument can only be used for its own special purpose, the observer must be provided with an ordinary single-bodied microscope for the examination of objects unsuited to the powers of the binocular. This last objection applies also to Professor Riddell's model.

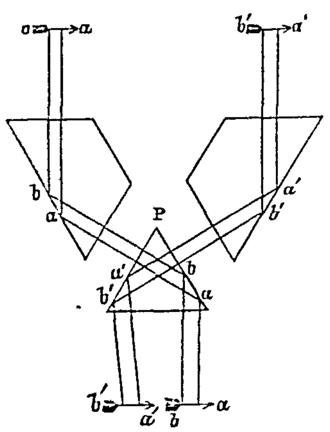


Fig. 22.—Nachet's Binocular Prisms.

It was for these reasons that Mr Wenham, fully impressed with the advantages of stereoscopic vision to the microscopist, set himself to devise a construction by which it might be obtained without the drawbacks inevitable in the working of Riddell's and Nachet's instruments; and he soon succeeded in accomplishing this on a plan which has proved not only convenient but practically satisfactory, notwithstanding its theoretical imperfection. Only the right half of the cone of rays proceeding upwards from the right half of the objective (*a*, fig. 24) is intercepted by a prism placed immediately over that half of its back lens, which, by two internal reflexions (as shown in fig. 25), sends its pencils obliquely upwards into the left-hand or secondary body L, whilst the pencils of the left half-cone pass uninterruptedly into the right-hand body R, and form an image that suffers no other deterioration than that which results from the halving of the angular aperture and the consequent loss of light. The moderate convergence of the two bodies (which, by varying the angles of the prism, may be made greater or less, so as to accord with the ordinary convergence of the optic axes in the individual observer) is much more generally suitable than the parallelism of MM. Nachet's earlier instrument; and the adjustment requisite for variation of distance between the eyes can be made by simply lengthening or shortening the bodies by drawing out or pushing in the diverging eye-pieces.

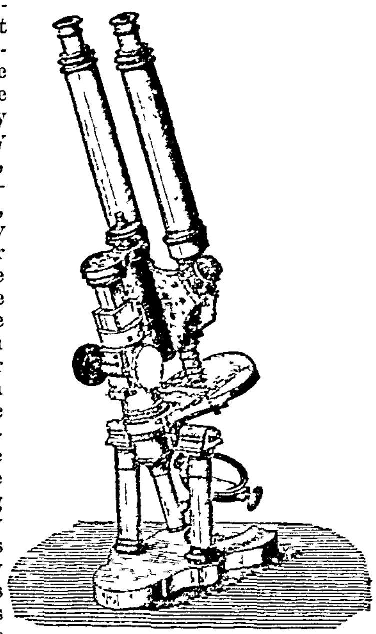


Fig. 23.—Nachet's Binocular Microscope.

It may be fairly objected to Mr Wenham's method (1) that, as the rays which pass through the prism and are obliquely reflected into the secondary body traverse a longer distance than those which pass on uninterruptedly into the principal body, the image formed by them will be somewhat larger than that which is formed by the other set, and (2) that the image formed by the rays which have been subjected to the action of the prism must be inferior in distinctness to that formed by the uninterrupted half of the cone of rays. But these objections are found to have no practical weight. For it is well known to those who have experimented upon the phenomena of stereoscopic vision (1) that a slight difference in the size of the two pictures is no bar to their perfect combination, and (2) that, if one of the pictures be good, the full effect of relief is given to the image, even though the other picture be faint and imperfect, provided that the outlines of the latter are sufficiently distinct to represent its perspective projection. Hence if, instead of the two equally half-good pictures which are obtainable by MM. Nachet's original construction, we had in Mr Wenham's one good and one indifferent picture, the latter would be decidedly preferable. But, in point of fact, the deterioration of the second picture in Mr Wenham's arrangement is less considerable than that of both pictures in the original arrangement of MM. Nachet; so that the optical performance of the Wenham binocular is in every way superior. It has, in addition, these further advantages over the preceding:—first, the greater comfort in using it (especially for some length of time together) which results from the convergence of the axes of the eyes at their usual angle for moderately near objects; second, that this binocular arrangement does not necessitate a special instrument, but may be applied to any microscope which is capable of carrying the weight of the secondary body,—the prism being so fixed in a movable frame that it may in a moment be taken out of the tube or replaced therein, so that when it has been removed the principal body acts in every respect as an ordinary microscope, the entire cone of rays passing uninterruptedly into it; and, third, that the simplicity of its construction renders its derangement almost impossible. Hence it is the one most generally preferred by microscopists who use the long-bodied English model.

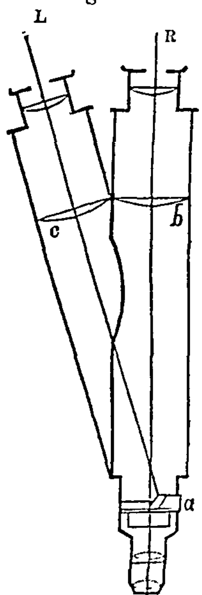


Fig. 24.—Wenham's Stereoscopic Binocular Microscope.

For short-bodied Continental microscopes, however, MM. Nachet

[1] See Silliman's *Journal*, vol. xv., 1853, p. 68; and *Quart. Jour. of Micros. Sci.*, vol. i., 1853, p. 236.
[2] *Quart. Jour. of Micros. Sci.*, vol. ii., 1854, p. 18.

have devised an arrangement of two prisms, based on Mr Wenham's fundamental idea of deflecting one half of the cone of rays into a secondary body, whilst the other half proceeds onwards without change of direction into the principal body. And it is an interesting feature in this construction that, by a simple change in the *position of the dividing prism, the true "orthoscopic" image may be* made, by a "conversion of relief," to become "pseudoscopic." [1]

The effect of stereoscopic projection may be attained, however, without a double body, by the insertion of a suitably constructed binocular eye-piece into the body of any ordinary monocular microscope. A plan of this kind was first successfully worked out by Mr Tolles (the very able optician of Boston, United States), who interposed a system of prisms similar to that devised by MM. Nachet (fig. 22), but on a much larger scale, between an "erector" (resembling that used in the eye-piece of a day telescope) and a pair of ordinary Huygenian eye-pieces, the central or dividing prism being placed at or near the plane of the secondary image formed by the erector, while the two eye-pieces are placed immediately above the lateral prisms,—the combination thus making that division in the pencils forming the secondary (erected) image which it makes in the Nachet binocular in the pencils emerging from the objective.

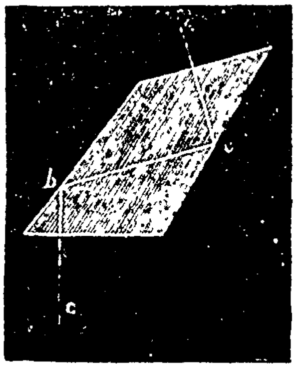


FIG. 25.—Wenham's Binocular Prism.

A stereoscopic eye-piece of a very different construction has been recently devised by Professor Abbe, who, making use, for the division between the two eye-pieces of the rays going to form the first image, of an arrangement of prisms essentially similar to that devised by Mr Wenham for his non-stereoscopic binocular (fig. 27), obtains either an orthoscopic or a pseudoscopic effect by placing on each eye-piece a cap with a semicircular diaphragm, so as to extinguish half of each of the cones of rays that form the two retinal images. While in one position of the diaphragms true stereoscopic or orthoscopic relief is given, it is sufficient to turn the diaphragms into the opposite position to obtain a pseudoscopic conversion.[2] It appears, however, that this arrangement, though possessing points of great interest in relation to the theory of binocular vision, is not likely to supersede the ordinary Wenham prism.

It must be obvious to every one who studies with sufficient attention the conditions under which true stereoscopic relief can be given that no combination of two dissimilar retinal perspectives can be satisfactory unless the visual pictures represent with tolerable distinctness the features of the object that lie in different focal planes. This is provided for, in ordinary vision, by the power of accommodation possessed by the eye, which, while focussed exactly to any one plane, can also include in its visual picture (within certain limits) what is either nearer or more remote. Now it seems probable that, as Professor Abbe has urged, this power of accommodation comes into play in microscopic stereoscopy, but there can be no question that the visual distinctness of the parts of an object lying within and beyond the focal plane, and therefore the completeness of the stereoscopic image, mainly depends upon the "focal depth" of the objective employed,—which, as already explained, is a function of its angular aperture. When, however, objectives of long focus and small aperture are employed in binocular microscopy, although each of the two perspective projections may be fairly distinct throughout, the effect of solid relief will be very inconsiderable, because the pictures are not sufficiently dissimilar to one another,—the case being exactly analogous to that of the stereoscopic combination of two photographic portraits taken at an angle of no more than a few degrees from each other. Still, with an objective of 1½ inches focus and an angular aperture of from 15° to 20°, a very distinct separation is made of the focal planes of transparent sections of structures having no great minuteness of detail,—such, especially, as injected preparations,—the solid forms of their capillary networks being presented to the mind's eye with a vividness that no monocular representation of them can afford. When a 1 inch objective of 20° or 25° is used, the stereoscopic effect becomes much more satisfactory; so that objects of moderate projection (such as many of the siliceous *Polycystina*, *Diatomaceæ*, &c.) can be seen in nearly their natural projection, and, if the focal adjustment is made for a medium plane, with tolerable distinctness both of their nearer and remoter parts. With a ⅔ inch of 30° or 35°, the stereoscopic relief becomes more pronounced; but the diminution of the focal depth prevents the several planes of objects in strong relief from being as distinctly seen at the same time. A ½ inch objective of about 40° of aperture, however, affords the most satisfactory results with suitable objects,—full stereoscopic relief being gained without exaggeration, so as to present, *e.g.*, the discoidal diatoms and the smaller *Polycystina* in their true forms, whilst their nearer and more remote parts are seen with sufficient distinctness to require only a very slight adjustment of the focus for their perfect definition. Still more minute objects may be well shown by $\frac{4}{10}$ths and ¼th objectives whose angular aperture does not exceed 50°; but it can be shown both theoretically and practically[3] that the dissimilarity of the two perspective projections of objects in relief formed by objectives of any angle much exceeding 40° is such as to exaggerate the stereoscopic effect; besides which, every enlargement of angular aperture so greatly diminishes the focal depth of the objectives that only those parts of the objects which lie very near the focal plane can be seen with distinctness sufficient for the formation of a good stereoscopic image. Hence, for the purposes of minute histological research, the stereoscopic binocular is (in the present writer's opinion) almost valueless; since, if any distinct perspective differentiation can be gained with objectives of the short focus and enlarged angle that are most suitable to such investigations, that differentiation will be so great as to produce a highly exaggerated stereoscopic effect. If such objectives be used binocularly at all, they must be so mounted that their back lenses are in very close proximity to the prism; and the (transparent) object must be illuminated by an achromatic condenser of sufficient aperture to send through it pencils of sufficient divergence to produce the secondary image.

In regard to the advantage derived from the use of the stereoscopic binocular, with the powers, and upon the objects, suitable to produce the true effect of solid form, the writer can unhesitatingly assert, as the result of a long and varied experience, that in no other way could he as certainly or as vividly image those forms to himself, and that in prolonged work upon such subjects he is conscious of a great saving of fatigue, which seems attributable not merely (perhaps not so much) to the conjoint use of both eyes as to the absence of the mental effort required for the interpretation of the microscopic picture, when the solid form of the object has to be ideally constructed from it (chiefly by means of the information obtainable through the focal adjustment), instead of being directly presented to the mind's eye.[4]

Non-Stereoscopic Binoculars.—The great comfort which is experienced by the microscopist in the conjoint use of both eyes has led to the invention of more than one arrangement by which this can be secured when those high powers are required which cannot be employed with the ordinary stereoscopic binocular. This is accomplished by Messrs Powell and Lealand by taking advantage of the fact that, when a pencil of rays falls obliquely upon the surface of a refracting medium, a part of it is reflected without entering that medium at all. In the place usually occupied by the Wenham prism they interpose an inclined plate of glass with parallel sides, through which one portion of the rays proceeding upwards from the whole aperture of the objective passes into the principal body with very little change in its course, whilst another portion is reflected from its surface into a rectangular prism so placed as to direct it obliquely upwards into the secondary body (fig. 26). Although there is a decided difference in brightness between the two images, that formed by the reflected rays being the fainter, yet there is marvellously little loss of definition in either, even when the $\frac{1}{25}$ inch objective is used. The disk and prism are fixed in a short tube, which can be readily substituted in any ordinary binocular microscope for the one containing the Wenham prism.

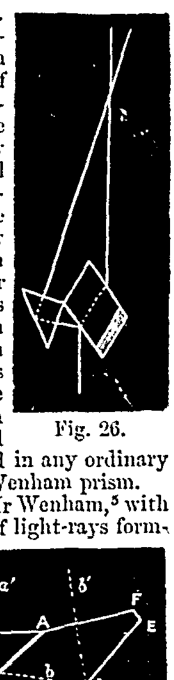


Fig. 26.

Other arrangements were devised long ago by Mr Wenham,[5] with a view to obtain a greater equality in the amount of light-rays forming the two pictures; and he has latterly carried one of these into practical effect, with the advantage that the compound prism of which it consists has so nearly the same shape and size as his ordinary stereoscopic prism as to be capable of being mounted in precisely the same manner, so that the one may be readily exchanged for the other. The axial ray *a*, proceeding upwards from the objective, enters the prism ABDEF (fig. 27) at right angles to its lower face, and passes on to *c*, where it meets the inclined face AB, at which this prism is nearly in contact with the oblique face of the right-angled

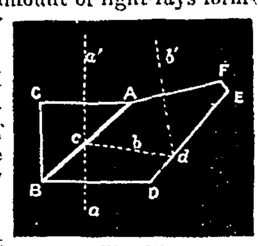


Fig. 27.

[1] See *Trans. of Roy. Micros. Soc.*, N. S., vol. xv., 1867, p. 105; and *Monthly Micros. Jour.*, vol. i., 1869, p. 31.

[2] See *Jour. of Roy. Micros. Soc.*, 2d ser., vol. i., 1881, p. 298.

[3] See *The Microscope and its Revelations*, 6th ed., pp. 42–44.

[4] A very elaborate investigation, by Professor Abbe, "On the Conditions of Orthoscopic and Pseudoscopic Effects in the Binocular Microscope," will be found in the *Jour. of the Roy. Micros. Soc.*, 2d ser., vol. i., 1881, p. 203.

[5] *Transactions of the Micros. Soc.*, N. S., vol. xiv., 1866, p. 105.

prism ABC. By internal reflexion from the former and external reflexion from the latter about half the beam b is reflected within the first prism in the direction cb, while the other half proceeds straight onwards through the second prism, in the direction ca', so as to pass into the principal body. The reflected half, meeting at d the oblique (silvered) surface DE of the first prism, is again reflected in the direction db', and, passing out of that prism perpendicularly to its surface AF, proceeds towards the secondary body. The two prisms must not be in absolute contact along the plane AB, since, if they were, Newton's rings would be formed; and much nicety is required in their adjustment, so that the two reflexions may be combined without any blurring of the image in the secondary body.

For the prolonged observation, under high powers, of objects not requiring the extreme of perfection in definition,—such, for example, as the study of the cyclosis in plants,—great advantage is gained from the conjoint use of both eyes by one of the above arrangements.

Mechanical Construction of the Microscope.

The optical arrangements on which the working of the compound achromatic microscope depends having now been explained, we have next to consider the mechanical provisions whereby they are brought to bear upon the different purposes which the instrument is destined to serve. Every complete microscope must possess, in addition to the lens or combination of lenses which affords its magnifying power, a stage whereon the object may securely rest, a concave mirror for the illumination of transparent objects from beneath, and a condensing-lens for the illumination of opaque objects from above.

1. Now, in whatever mode these may be connected with each other, it is essential that the optical part and the stage should be so disposed as either to be altogether free from tendency to vibration or to vibrate together; since it is obvious that any movement of one, in which the other does not partake, will be augmented to the eye of the observer in proportion to the magnifying power employed. In a badly-constructed instrument, even though placed upon a steady table resting upon the firm floor of a well-built house, when high powers are used, the object is seen to oscillate so rapidly at the slightest tremor—such as that caused by a person walking across the room, or by a carriage rolling by in the street—as to be frequently almost indistinguishable; whereas in a well-constructed instrument scarcely any perceptible effect will be produced by even greater disturbances. Hence, in the choice of a microscope, it should always be subjected to this test, and should be unhesitatingly rejected if the result be unfavourable. If the instrument should be found free from fault when thus tested with high powers, its steadiness with low powers may be assumed; but, on the other hand, though a microscope may give an image free from perceptible tremor when the lower powers only are employed, it may be quite unfit for use with the higher. The method still adopted by some makers, of supporting the body by its base alone, is the worst possible, especially for the long body of the large English model, since any vibration of its lower part is exaggerated at its ocular end. The firmer the support of the body along its length the less tremor will be seen in the microscopic image.

2. The next requisite is a capability of accurate adjustment to every variety of focal distance, without movement of the object. It is a principle universally recognized in the construction of good microscopes that the stage whereon the object is placed should be a fixture, the movement by which the focus is to be adjusted being given to the optical portion. This movement should be such as to allow free range from a minute fraction of an inch to three or four inches, with equal power of obtaining a delicate adjustment at any part. It should also be so accurate that the optic axis of the instrument should not be in the least altered by any movement in a vertical direction, so that, if an object be brought into the centre of the field with a low power, and a higher power be then substituted, the object should be found in the centre of its field, notwithstanding the great alteration in the focus. In this way much time may often be saved by employing a low power as a "finder" for an object to be examined by a higher one; and when an object is being viewed by a succession of powers little or no readjustment of its place on the stage should be required. A rack-and-pinion adjustment, if it be made to work both tightly and smoothly, answers sufficiently well for the focal adjustment, when objectives of low power only are employed. But for any lenses whose focus is less than half an inch a "fine adjustment," or "slow motion," by means of a screw-movement operating either on the object-glass alone or on the entire body (preferably on the latter), is of great value; and for the highest powers it is quite indispensable. It is essential that in this motion there should be no "lost time," and that its working should not produce any "twist" or displacement of the image. In some microscopes which are provided with a fine adjustment the rack-and-pinion movement is dispensed with, the "coarse adjustment" being given by merely sliding the body up and down in the socket which grasps it; but this plan is only admissible where, for the sake of extreme cheapness or portability, the instrument has to be reduced to the form of utmost simplicity, as in figs. 28, 29.

3. Scarcely less important than the preceding requisite, in the case of the compound microscope, especially with the long body of the ordinary English model, is the capability of being placed in either a vertical or a horizontal position, or at any angle with the horizon, without deranging the adjustment of its parts to each other, and without placing the eye-piece in such a position as to be inconvenient to the observer. It is certainly a matter of surprise that some microscopists, especially on the Continent, should still forego the advantages of the inclined position, these being attainable by a very small addition to the cost of the instrument; but the inconvenience of the vertical arrangement is much less when the body of the microscope is short, as in the ordinary Continental model; and there are many cases in which it is absolutely necessary that the stage should be horizontal. This position, however, can at any time be given to the stage of the inclining microscope, by bringing the optic axis of the instrument into the vertical direction. In ordinary cases, an inclination of the body at an angle of about 55° to the horizon will usually be found most convenient for unconstrained observation; and the instrument should be so constructed as, when thus inclined, to give to the stage such an elevation above the table that, when the hands are employed at it, the arms may rest conveniently upon the table. In this manner a degree of support is attained which gives such free play to the muscles of the hands that movements of the greatest nicety may be executed by them, and the fatigue of long-continued observation is greatly diminished. When the ordinary camera lucida[1] is used for drawing or measuring, it is requisite that the microscope should be placed horizontally. It ought, therefore, to be made capable of every such variety of position; and the stage must of course be provided with some means of holding the object, whenever it is itself placed in such a position that the object would slip down unless sustained.

4. The last principle on which we shall here dwell, as essential to the value of a microscope designed for ordinary work, is simplicity in the construction and adjustment of every part. Many ingenious mechanical devices have been invented and executed for the purpose of overcoming difficulties which are in themselves really trivial. A moderate amount of dexterity in the use of the hands is sufficient to render most of these superfluous; and without such dexterity no one, even with the most complete mechanical facilities, will ever become a good microscopist. There is, of course, a limit to this simplification; and no arrangement can be objected to on this score which gives advantages in the examination of difficult objects, or in the determination of doubtful questions, such as no simpler means can afford. The meaning of this distinction will become apparent if it be applied to the cases of the mechanical stage and the achromatic condenser. For, although the mechanical stage may be considered a valuable aid in observation, as facilitating the finding of a minute object, or the examination of the entire surface of a large one, yet it adds nothing to the clearness of our view of either; and its place may in great degree be supplied by the fingers of a good manipulator. On the other hand, the use of the achromatic condenser not only contributes very materially, but is absolutely indispensable, to the formation of a perfect image, in the case of many objects of a difficult class; the want of it cannot be compensated by the most dexterous use of the ordinary appliances; and consequently, although it may fairly be considered superfluous as regards a large proportion of the purposes to which the microscope is directed, whether for investigation or for display, yet as regards the particular objects just alluded to it is a no less necessary part of the instrument than the achromatic objective itself.

As a typical example of the simplest form of compound microscope that is suitable for scientific research,—which, with various modifications of detail, is the one generally employed on the Continent,—the *Microscope de dissection et d'observation* (fig. 28) of M. Nachet, especially as constructed for portability (figs. 29–31), seems particularly worthy of description. In its vertical form (fig. 28) the solid foot to which the mirror is pivoted gives support to the pillar F, to the top of which the stage P, having a diaphragm-plate beneath it, is firmly attached. On the top of this pillar the tubular stem A is fitted in such a manner that it may be removed by unscrewing the large milled head L,—though, when this is well screwed down, the stem stands quite firmly. This stem bears at its summit a short horizontal arm, which carries a strong vertical tube that firmly grasps the "body" of the microscope, while permitting this to be easily slid upwards or downwards, so as to make a "coarse adjustment" of the focus. The "fine adjustment" is made by turning the milled head V, which either presses down the outer tube of the stem, or allows it to be raised by the upward pressure of a strong spiral spring in its interior. By unscrewing the milled head L, the stem A with its arm and compound body can be detached from the pillar; and, a small light arm H holding either single lenses or doublets being slid into this, a convenient dissecting microscope is thus provided. The only drawback in the construction of this simple model is its not being provided with a joint for

[1] A camera lucida adapted for use with the vertical microscope has been devised by M. Nachet.

the inclination of the body; but this is introduced into the portable form of the instrument shown in fig. 29, the basal portion of which (fig. 30) can be used, like that of the preceding model, as a simple microscope, and, by a most ingenious construction, can be so folded as to lie flat in a shallow case (fig. 31) that holds also the upper part with the objectives of both the simple arm and the com-

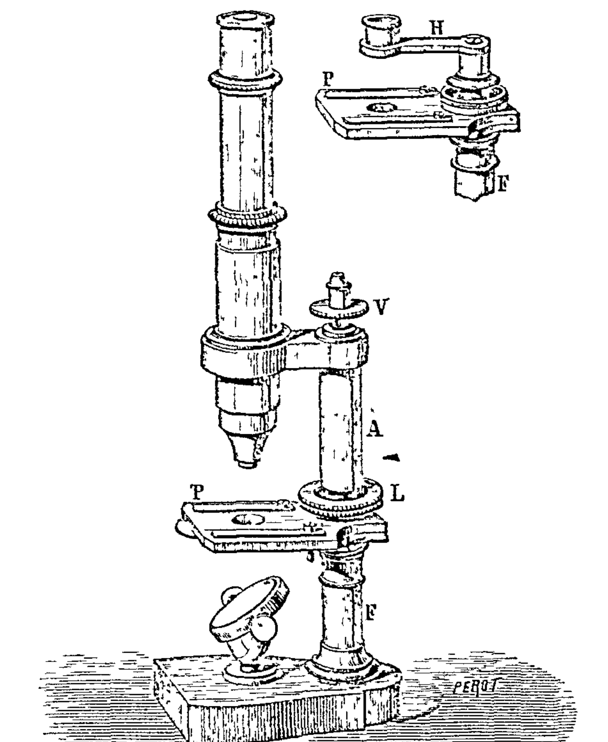


Fig. 28.—Nachet's Combined Simple and Compound Microscope.

pound body. M. Nachet now connects his objectives with the body of his microscopes, not by a screw, but by a cylindrical fitting held in place by the pressure of a spring-clip against a projecting shoulder. This method not only allows one objective to be removed and replaced by another much more readily than does the screw-fitting, but also renders the centring of different objectives more exactly conformable. It may be safely affirmed that a very large proportion of the microscopic work of the last half-century, which has given an entirely new aspect to biological science, has been done by instruments of this simple Continental type.

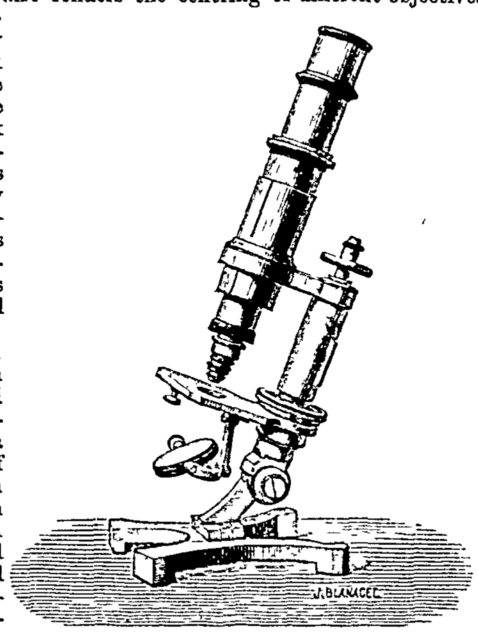


Fig. 29.—Nachet's Portable Compound Microscope.

A larger model, however, was from the first adopted by English opticians; and, as a typical example of the general plan of construction now most followed both in England and in the United States, the improved Jackson-Zentmayer microscope of Messrs Ross (fig. 32) may be appropriately selected. The tripod base of this instrument carries two pillars, between which is swung upon a horizontal axis (capable of being fixed in any position by a tightening screw) a solid "limb," with which all the other parts of the instrument are connected,—a plan of construction originally devised by Mr George Jackson. The binocular body, having at its lower end (as in fig. 24) an opening into which either of the Wenham prisms can be inserted, and at its top a rack movement for adjusting the eye-pieces to the distance between the eyes of the observer, is attached to a racked slide, which is so acted on by the large double milled

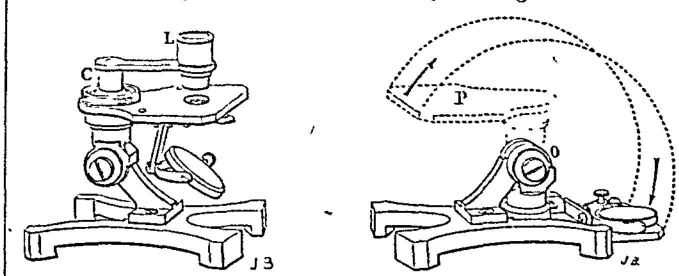


Fig. 30.—Nachet's Portable Dissecting Microscope; on the left as set up for use, on the right as having the stage P turned back upon the joint O, so as to lie flat on the bottom of the case.

head in the upper part of the limb as to give a "quick" upward or downward motion to the body; while the "slow" motion, or fine

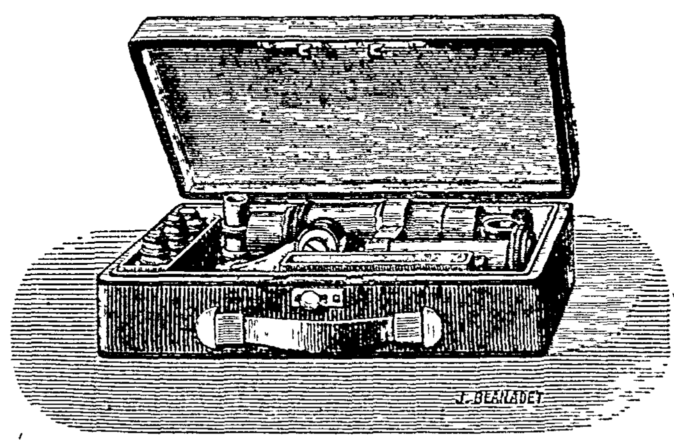


Fig. 31.—Nachet's Portable Compound and Dissecting Microscope, as packed in case.

adjustment, is given by means of the vertical micrometer screw at the back of the limb, which raises or lowers a second slide behind the rack.[1] The stage is supported upon a firm ring, which is immovably fixed, not to the limb, but to a strong conical pivot which passes through the limb, to be clamped by a screw-nut at its back,—the purpose of this being to allow the whole stage to be inclined to one side or the other at any angle, so that a solid object may be viewed sideways or from below, as well as from above. Upon this ring the stage rotates horizontally, its angular movement being measured by a graduated scale and vernier at its edge; and it can be fixed in any azimuth by a clamping-screw beneath. Rectangular movement is given to the traversing platform which carries the object by two milled heads on the right of the stage, the whole construction of which is adapted to allow light of extreme obliquity to be thrown upon the object from beneath. On the strong pivot by which the stage is

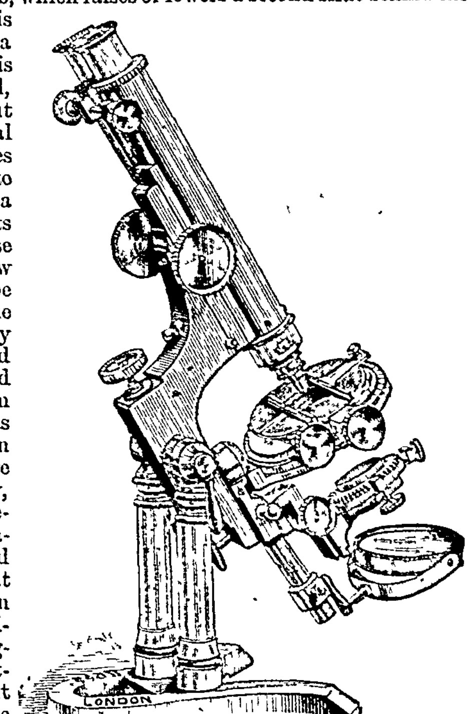


Fig. 32.—Ross's Jackson-Zentmayer Compound Microscope.

[1] In the older form of construction still retained by some makers the fine adjustment acts directly on the objective, the fitting of which is made to slide up and down within the nose of the body; but this plan is attended with many disadvantages.

attached to the limb (the axis of which passes through the point at which the object-plane is intersected by the optic axis of the body) is hung the swinging tail-piece invented by Mr Zentmayer of Philadelphia, which, carrying the whole illuminating apparatus, may be so set as to give to the axis of the illuminating pencil any required degree of obliquity. To the upper part of it is attached a rack-and-pinion movement carrying the "substage," which is provided with two milled-headed screws for centring it precisely with the microscope-body. Into this may be fitted the achromatic condenser, parabolic illuminator, polarizing prism, or any other kind of illuminating apparatus; whilst at its lower end it carries the mirror, the position of which may be varied by sliding its fitting up or down the "tail-piece," or by turning the arm which carries it to one side or the other; while, if direct illumination from a lamp should be preferred, it may be turned altogether aside. By swinging the tail-piece round above the stage, oblique light may be reflected from the mirror, through the condenser, upon the upper surfaces of objects. The condenser usually fitted to this instrument is of about $\frac{4}{10}$ inch focus, with a large back lens; behind which are placed an iris-diaphragm for reducing the light to the central rays, and a diaphragm-plate with apertures of the various forms most suited for the resolution of lined objects by oblique rays.

No instrument, in the writer's judgment, is better adapted than this for the highest purposes of microscopical research. It works admirably with every power from the lowest to the highest, and is capable of receiving any one of the numerous pieces of apparatus which have been devised for special researches of various kinds. The detailed description of these not being here admissible, it will be sufficient to indicate the polariscope and the spectroscope as the most important of these accessories.

Micrometry.

The microscopist has constant need of some means of taking exact measurements of the dimensions of the minute objects, or parts of objects, on the study of which he is engaged; and the accuracy of the operation will of course be proportioned to the correctness of the standard used, and the care with which it is applied.

The instruments employed in microscopic micrometry are of two kinds, the measurement being taken in one by the rotation of a fine screw with a divided milled head, whilst in the other a slip of glass ruled with lines at fixed distances gives a scale which forms a basis of computation. Each of these has its advantages and its disadvantages.

The stage-micrometer constructed by Frauenhofer was formerly much used by Continental microscopists, and has the advantage of indicating the actual dimensions of the objects to be measured; but it has the two special disadvantages that a sufficiently small value cannot be conveniently given to its divisions, and that any error in its construction and working is augmented by the whole magnifying power employed. This instrument has now, however, almost entirely given place to one of those to be next described.

The screw-micrometer ordinarily used in astronomical measurements (see Micrometer) can be adapted to the eye-piece of the microscope in a manner essentially the same as that in which it is applied to the telescope,—its two parallel threads—of which one is fixed and the other made to approach towards or recede from this by the turning of the screw—being placed in the focus of the eye-glass, and being therefore seen as lines crossing its field of view. The object is so focussed that its image is formed in the same plane; and, the latter being brought into such a position that one of its ends or margins lies in optical contact with the fixed line, the screw is turned so as to bring the movable line into the like coincidence with the other. But the distance between the lines, as given by the number of divisions of the micrometer, will here be the measurement, not of the object itself, but of its magnified image; and the value of these divisions, therefore, will depend upon the amplification given by the particular objective used. Thus, suppose each division of the micrometer to have an actual value of $\frac{1}{10000}$th of an inch, and the visual image to have one hundred times the linear dimensions of the object, the theoretical micrometric value of each division would be $\frac{1}{100}$th of $\frac{1}{10000}$th, or one-millionth, of an inch,—a degree of minuteness, however, not practically attainable. It is necessary, moreover, to determine the micrometric value of the divisions of the micrometer, not only for every objective, but for variations in the conditions under which that objective may be employed, as regards the length of the tube or "body" of the microscope, which is varied not only by the draw-tube, but also, in many cases, in the working of the fine adjustment or slow motion, and also, in the case of the large-angled powers furnished with adjustment for thickness of the covering-glass, for the degree of separation of the front- from the back-glasses of the objective, which makes a very sensible difference in its magnifying power. This determination is made by means of a divided glass stage-micrometer put in the place of the object, so that the lines ruled upon it at fixed intervals shall be projected upon the field of view. The stage-micrometer is usually ruled either to 1000ths of an inch or 100ths of a millimetre; and it is convenient that one of the divisions of its image should be made to coincide exactly with a certain number of divisions of the screw-micrometer. This may be done by lengthening the draw-tube, so as to increase the amplification of the scale until coincidence has been reached; and the exact amount of this lengthening should be noted,—as should also the precise position of the milled head of the slow motion (if it acts on the objective, instead of on the body as a whole), and of the adjusting screw-collar of the objective itself. Thus, if two lines of the stage-micrometer separated by 1000th of an inch be brought into coincidence with the two threads of the eye-piece micrometer, separated by forty divisions of the screw milled head, the value of each of those divisions is $\frac{1}{40000}$th of an inch. If the above conditions be precisely recorded for each objective used in micrometry, the micrometric value of the divisions remains the same for that objective, whenever it is employed under the same conditions.

The errors to which micrometers are subject arise (1) from inequalities in the ruling of the stage-micrometer, (2) from irregularities in the screw of the eye-piece micrometer, (3) from "lost time" in its working, and (4) from the thickness of its threads. In order to eliminate the first and second, it is well to determine the relation of the divisions of the two micrometers by the comparison of a considerable number of both; the third proceeds from an imperfection of workmanship which, if it shows itself sensibly, entirely destroys the value of the instrument, while the fourth can be rectified by the exercise of skill and judgment on the part of the observer. For, if the micrometer is so constructed as to read zero when one thread lies exactly upon the other, its divisions indicate the distance between the axes of these threads when separated; and the dimensions of any object (such as a blood-corpuscle) lying between their borders will obviously be too great by half the thickness of the two threads, that is, by the entire thickness of one thread. When, on the other hand, the measurement is being made (as of the distances of the striæ on diatoms) by the coincidence between certain lines on the object and the axes of the threads of the micrometer, the dimensions indicated by the divisions of the screw milled-head will be correct.

The costliness of a well-constructed screw-micrometer being a formidable obstacle to its general use, a simpler method (devised by Mr George Jackson) is more commonly adopted, which consists in the insertion of a ruled-glass scale into the focus of an ordinary Huygenian eye-piece, so that its lines are projected on the field of view. This scale (ruled, like an ordinary measure, with every fifth line long, and every tenth line double the length of the fifth) is fixed in a brass inner frame, that has a slight motion in the direction of its length within an outer frame; and this last, being introduced through a pair of slits into the eye-piece just above the diaphragm, and being made to occupy the centre of the field, is brought exactly into focus by unscrewing the eye-glass as far as may be requisite. When the image of the object to be measured is brought by the focal adjustment of the object-glass into the same plane, a small pushing-screw at the end of the micrometer (whose action is antagonized by a spring at the other end) is turned until one of the long divisions of the scale is brought into optical contact with one edge of the image of the object to be measured, and the number of divisions is then counted to its other edge,—the operation being exactly that of laying a rule across the real object if enlarged to the size of its image. The micrometric value of each division of this eye-piece scale must be carefully ascertained for each objective, as in the case of the screw-micrometer, the error arising from inequality of its divisions being eliminated as far as possible by taking an average of several. The principal point of inferiority in this form of micrometer is that, as its divisions cannot be made of nearly so small a value as those of the screw-micrometer, an estimate of fractional parts of them often becomes necessary, which is objectionable as involving an additional source of error. To meet this objection, Hartnack has introduced the diagonal scale used in mathematical instruments before the invention of the vernier.

Another mode of making micrometric measurements, which for some purposes has considerable advantages, is to employ a stage-micrometer in combination with some form of camera lucida attached to the eye-piece of the microscope, so that the image of its divisions may be projected upon the same surface as that on which the image of the object is thrown. By first using the ruled stage-micrometer, and marking on the paper the average distance of its lines as seen in the central part of the field, and then ruling the paper accordingly, the micrometric value of the divisions so projected may be exactly determined for the objective employed and the distance of the drawing-plane from the eye-piece,—so that, when the image of any object is projected under the same conditions, the dimensions of that image or of any parts of it can be exactly measured upon the divided scale previously projected, and the true dimensions of the object thus easily ascertained. If, for example, the lines of a stage-micrometer ruled to the thousandth of an inch should, when thus projected, fall at a distance of an inch apart, then the application of an ordinary scale of inches (divided into tenths) to the image of an object projected by the same objective

and on the same plane would give its real dimensions in thousandths of an inch, while the tenths of the inch scale would represent a real dimension of as many ten-thousandths. It is often desirable to make such measurements from careful tracings of the outlines of objects, rather than from the visual images,—this plan being especially advantageous when the exact dimensions of many similar objects have to be compared, as in the case of blood-corpuscles, precise measurements of which are not unfrequently required in judicial inquiries. It was by the use of this method that the late Mr Gulliver made his admirable series of measurements of the average and extreme dimensions of the blood-corpuscles of different animals. And more recently Mr Dallinger has shown,—by first making a very fine camera lucida tracing of *Bacterium termo* under an amplification of 2000 diameters, and measuring the breadth of its body in the mode above indicated (which gave it as $\frac{1}{20400}$th of an inch), and then by magnifying his tracing from five to ten diameters, and comparing, by means of the screw-micrometer, the breadth of the flagellum with that of the body (which last proved to be just ten times as great),—that, although the theoretical limit of resolving power for closely approximated lines is $\frac{1}{140523}$th of an inch, a semitransparent filament whose breadth is not greater than $\frac{1}{200000}$th of an inch may be clearly discerned, and even measured with a close approximation to accuracy (*Jour. of Royal Micros. Society*, vol. i., 1879, p, 169). (W. B. C.)

MIDAS, king of Phrygia, is one of those half-legendary heroes in whom religious legends have gathered round a real person. The name Midas the king, ΜΙΔΑΙ ϜΑΝΑΚΤΕΙ, occurs on a very ancient tomb in the valley of the Sangarius, the legendary seat of the Phrygian kingdom (*Iliad* iii. 189). The Phrygian monarchy was destroyed by the Cimmerians about 670 B.C., and the last king Midas committed suicide by drinking bull's blood. The name Midas became in Greek tradition the representative of this ancient dynasty, but all that is told of him is religious myth. He is a figure in the cycle of Cybele legends, the son of the goddess and her first priest. He is also closely connected with the cultus of Dionysus, like the two heroic personages Marsyas and Silenus. The Midas legend was known on Mount Bermius in Macedonia, and must at one time have existed in Greece; two cities Midea, in Argolis and in Bœotia, recall the Phrygian city Midæium.

See Herod. viii. 138; Xen., *Anab.*, i. 2, 13; Paus. i. 45, &c.

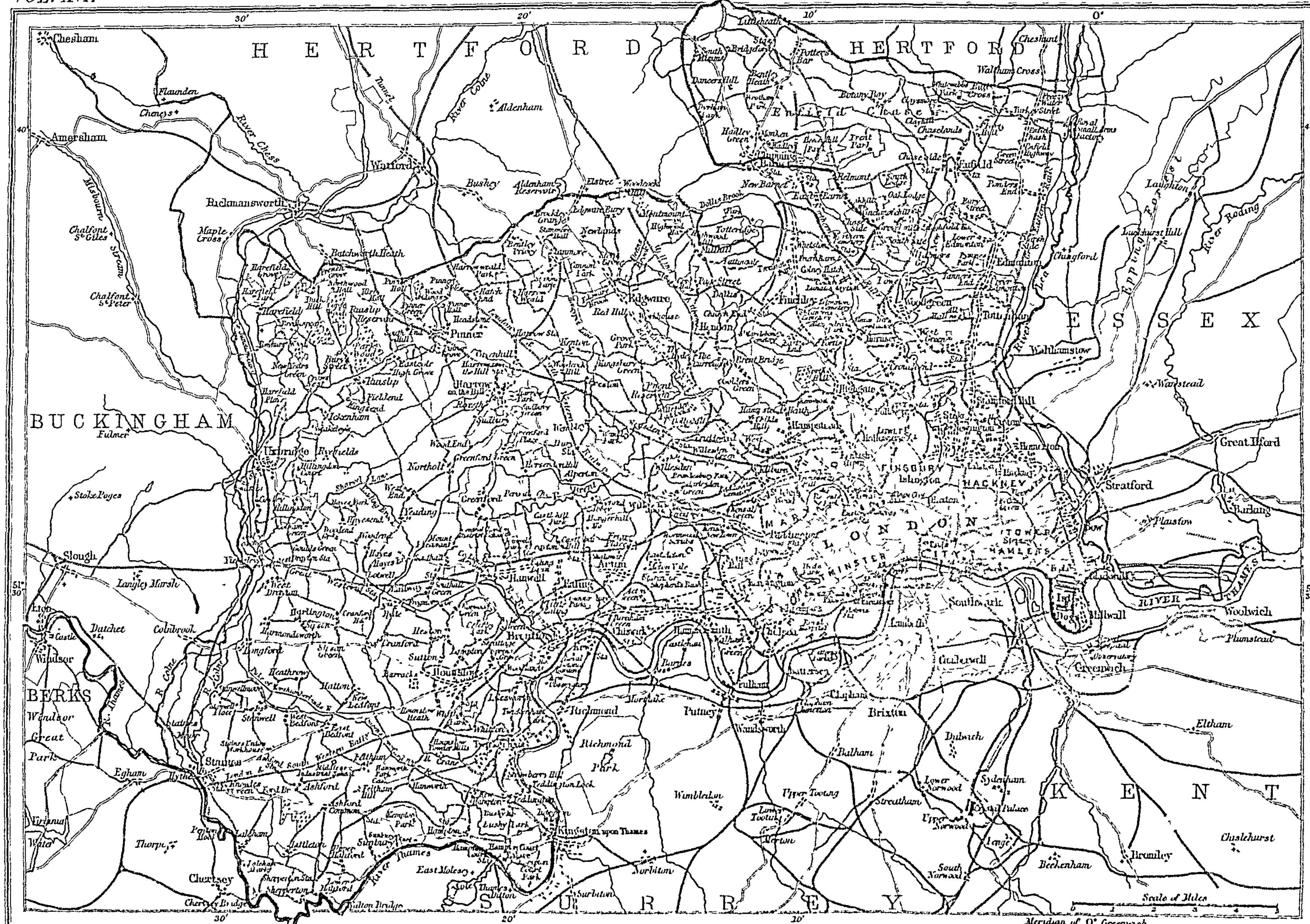
MIDDELBURG, in Holland, the ancient capital of the province of Zealand, situated in the middle of the island of Walcheren, is mentioned as early as 1153, and receives the title "town" in a charter granted it in 1227. It has all the characteristics of an old and worn-out place. The population (25,000 in 1739) had sunk to 12,000 or 13,000 by the beginning of the 19th century, and has only begun recently to increase again, being 15,939 in 1882. The dwelling-houses, which in 1739 were about 3800, are now but 3000, and of these about 600 are unoccupied. The vast warehouses and imposing mansions once belonging to wealthy families, which have either died out or left the place, call up the memory of that prosperity which Middelburg enjoyed before its extensive trade, with the East and West Indies, with England and Flanders, was ruined by the war with England and the French occupation. By the opening of the railway (1872) and of the ship canal (1873) to Flushing Middelburg was lifted out of its isolation, and, with the assistance of the chamber of commerce, manufacturing industries (iron, machinery, furniture, oil, cigars, &c.) were established; but the prosperity anticipated for Flushing, and consequently for Middelburg, remains unrealized. One of the chief sights of Middelburg is the splendid town-house, for the most part erected in 1512–13, with its front gable adorned with twenty-five statues of counts and countesses of Holland and Zealand; it contains the archives, and a most valuable antiquarian and historical collection. The abbey, begun in 1150, has frequently been the residence of royal visitors (Maximilian, Philip the Fair, Charles V., and so on down to Napoleon I., and William I., II., and III.); part of it is now an hotel, and part of it is occupied by the provincial authorities. The great hall of the building, in which the states of Zealand assemble, is adorned with beautiful tapestries by Jan de Maecht, representing the heroic feats of the men of Zealand in the contest with Spain. What was formerly the nave of the abbey church is now the New Church, and the ancient choir constitutes the Choir Church. The former contains a fine pulpit resting on an eagle, the monument of William, king of the Romans (d. 1256), and the tombs of Jan and Cornelis Evertsen, two naval heroes who fell in the war against England in 1666; the latter has the monuments of the learned Hadrian Junius and of Jan Pieterszoon. The provincial court, the corn exchange, the Hof St Joris and the Hof St Sebastian (formerly buildings belonging to the guilds of archers, and now places of amusement) deserve mention. The great museum of Zealand antiquities, collected by the Zealand Society of Arts and Sciences (founded at Flushing in 1769 and transferred to Middelburg in 1801), shows that the town is the intellectual centre of the province.

The principal facts in the history of Middelburg are the sieges by the Flemings in 1288, 1296, and 1303 (the last resulting in the capture of the town by Guy of Dampierre); the recovery of the town from the Spaniards in 1574, after an investment of nearly two years; the frequent disturbances among the townsfolk in the 17th and 18th centuries; the surrender to the English in 1809; and the arrival and departure of the French in 1809 and 1814.

MIDDLEBOROUGH, a town of the United States, in Plymouth county, Massachusetts, 34 miles south of Boston. It has a handsome town-hall and a public library, manufactures woollen goods, straw goods, shovels, shoes, carriages, &c., and in 1880 had 5237 inhabitants.

MIDDLESBROUGH, situated near the mouth of the Tees, on its south bank, in the North Riding of Yorkshire, has now become the principal seat of the English iron trade. It is a municipal and parliamentary borough, locally governed by a mayor and corporation, and returns a member to parliament. The earlier history of the place is meagre. Where Middlesbrough now stands (Graves's *History of Cleveland*) there were at one time a small chapel and priory founded by Robert de Brus of Skelton Castle. These were dedicated to St Hilda, and with some lands were given by De Brus to the abbey of St Hilda at Whitby in 1130. The priory fell into ruins at the time of the Reformation, and no trace now remains beyond some stones built into the wall of a brewery. The mayor's chair also is made from a fragment. In 1801 there were upon the site of Middlesbrough only four farm-houses. In 1829 a company styling itself the Middlesbrough Owners bought 500 acres of land, and commenced building the town. In 1830 the Stockton and Darlington Railway was extended from Stockton to Middlesbrough; four years later the town was lighted with gas; and after six years more a public market was established. The census of 1831 showed the population to be 154; that of 1841 showed 5709. In 1842 the opening of the docks gave additional importance to the town. First containing an area of 9 acres, they were extended in 1872 to 12 acres, with 1700 feet of quays. Vessels of 3000 tons burden can be accommodated. From the year 1851, when J. Vaughan discovered the presence of ironstone in the Eston Hills, the town advanced with rapid strides. When the jubilee of the town was held in 1881 (a year late) the population had risen to 55,934, the area to 2731 acres, and the rateable value to £140,000, the population of the parliamentary borough (area 4715 acres) being 72,145. In the district there are upwards of

MIDDLESEX


H E R T F O R D
E S S E X
B U C K I N G H A M
BERKS
K E N T
S U R R E Y
L O N D O N
FINSBURY
HACKNEY
TOWER HAMLETS
CITY
WESTMINSTER
MARYLEBONE
RIVER THAMES
Chesham
Amersham
Watford
Rickmansworth
Aldenham
Bushey
Barnet
Enfield
Edmonton
Tottenham
Walthamstow
Stratford
Great Ilford
Woolwich
Greenwich
Uxbridge
Harrow on the Hill
Pinner
Ruislip
Edgware
Hendon
Finchley
Hampstead
Islington
Southwark
Lambeth
Camberwell
Brixton
Clapham
Putney
Fulham
Chiswick
Brentford
Hounslow
Twickenham
Richmond
Kingston upon Thames
Staines
Slough
Windsor
Chertsey
Wimbledon
Dulwich
Sydenham
Bromley
Eltham
Chislehurst
Scale of Miles
Meridian of 0° Greenwich

130 blast furnaces, besides large iron and steel works; and the Thomas-Gilchrist process of making steel promises for Middlesbrough importance in the future as a steel entrepôt. The make of pig-iron in 1880 was 1,991,032 tons. There are also shipbuilding, potteries, chemical works, and a salt trade. Middlesbrough is well laid out, nearly all the streets lying at right angles to one another. Many of the churches and the exchange are handsome buildings, while the station of the North Eastern Railway is probably the finest in the north of England. A splendid park of 72 acres, the gift of the late H. F. W. Bolckow, adds greatly to the amenity of the town.

Plate III. MIDDLESEX, an inland county in the south-east of England, lying between 51° 25′ and 51° 40′ N. lat., and between 0° and 0° 36′ W. long. On the south it is divided from Surrey and Kent by the Thames, on the east from Essex by the Lea, on the west from Buckinghamshire by the Colne, and on the north from Hertfordshire by a partly artificial and very irregular line. Although with the exception of Rutland it is the smallest county in England, its population is exceeded by that of Lancashire only. Its total area is 181,317 acres, of which 2592 acres are common or waste lands. The longest straight line that can be drawn in the county is one of nearly 28 miles from the north-eastern extremity near Waltham Abbey to the south-western at Staines. From north to south in the broadest part the distance is about 15 miles.

Surface and Geology.—The greater portion of the county is flat, although there are sufficient undulations to allow of a proper drainage of the land. A range of hills runs along the Hertfordshire border by Barnet, Elstree, Stanmore, and Pinner, averaging 100 feet in height; another range occupies the ground just north of London by Hornsey, Highgate, and Hampstead; Harrow occupies an isolated eminence between the two ranges.

The county lies entirely within the basin of the Thames, and the London Clay extends over a large portion of the surface. This formation stretches from the mouth of the estuary of the Thames to the neighbourhood of Marlborough. It attains its greatest breadth (little short of 30 miles) in the neighbourhood of London, and extends northward until it is lost beneath the drift of Suffolk and Norfolk. The following is a table of the various beds of rock which occur at the surface, with their greatest thickness (in feet) in the district:—

Alluvium (recent river deposits)	15
Post-Pliocene Tertiaries.	
Post-glacial beds (brick-earth, gravel, &c.)	50
Glacial drift (boulder clay, gravel, &c.)	80
Eocene Tertiaries.	
Lower Bagshot sands	100
London Clay	420
Woolwich and Reading beds	90
Cretaceous.	
Chalk with flints	800

Chalk comes to the surface in so very few places that it is scarcely worth mention. It is seen near Harefield and on the north-west side of South Mimms. The depth from the surface to the chalk varies greatly in different parts of the county. This has been proved by the borings for wells; thus at Isleworth the depth is 400 feet and at Hampstead 378, while at Ruislip it is 76 feet and at Pinner only 60. The Reading beds (plastic clays) are brought to the surface at Windsor. They follow roughly the course of the river Colne from the north of Uxbridge along the flank of the hills north-eastward, but are sometimes cut back southward along small side valleys. An outlying mass is exposed at Pinner. The Bagshot sands, consisting of gravel and sand permeable to water, once stretched over the whole extent of the London Clay, but they are now to be found only on the high grounds at Hampstead, Highgate, and Harrow. A corner of the main mass enters the south-west corner of the county near Littleton. Beds of brick-earth occur in the drift between West Drayton and Uxbridge.

Several deep borings in the London basin prove the existence beneath the chalk of beds which do not crop out in Middlesex. Three of these are in the county; and the most interesting is that at Meux's Brewery, Tottenham Court Road (about 1146 feet), which passes through the following formations:—gravel and clay, 21 feet; London Clay, 64 feet; Reading beds, 51 feet; Thanet sand, 21 feet; chalk, 655 feet; Upper Greensand, 28 feet; gault, 160 feet; Lower Greensand, 64 feet; Devonian, 80 feet.

Rivers and Canals.—The Thames is very tortuous in the 44 miles of its course from Staines to Blackwall, and makes a remarkable bend at the eastern limit of the county where it forms the so-called Isle of Dogs. The width at Staines is 200 feet, at Chiswick opposite Barnes 340 feet, at Hammersmith 525 feet, at Fulham 820 feet, at Westminster Bridge 1100 feet, but at London Bridge it is less than 800 feet; above the junction of the Lea at the Isle of Dogs the width is 1350 feet. The ordinary rise of the tide at London Bridge is 16 feet, and the tide-way ends at Teddington. The port of London begins below London Bridge, and the channel for from 2 to 3 miles is called the Pool.

The Colne from Hertfordshire enters Middlesex at the north-western corner of the county. It then runs south, joining the Thames at Staines, and in its course divides Middlesex from Buckinghamshire for 15 miles. After the river leaves Uxbridge it divides out into several small channels. The Lea from Hertfordshire enters Middlesex at the north-eastern corner of the county near Waltham Abbey. It runs south, dividing Middlesex from Essex for 15 miles, and falls into the Thames at Bow Creek. Several branches flow off from the river during its course. The Brent from Hertfordshire enters Middlesex near Finchley. It takes a circuitous direction southward through the middle of the county by Hendon, Kingsbury, Twyford, Greenford, and Hanwell to the town of Brentford, where it unites with the Thames. Where the river crosses the Edgeware Road (about 3 miles south of the town of Edgeware) it is expanded by artificial means into an extensive reservoir. The Cran (or Yedding Brook) rises in the district between Harrow and Pinner and flows under Cranford Bridge; it crosses Hounslow Heath, and bends round to Twickenham and Isleworth, where in a divided stream it falls into the Thames.

There were several other small streams in the neighbourhood of London which have left their mark in the names of places, but which are now merely sewers, such as the Wallbrook, the Westbourn, the Tyburn, the Fleet river, &c. The last-mentioned, which runs into the Thames near Blackfriars Bridge, was formerly navigable as far as Holborn Bridge; but, the Fleet Ditch, as it was then called, having become in the last century a dangerous nuisance, the lord mayor and citizens were empowered by Act of Parliament to arch it over. The work was commenced in 1734, and in 1737 Fleet market, occupying the site of the space from Holborn Bridge to Fleet Bridge, was opened to the public. The New River, an artificial water-course constructed by Sir Hugh Myddelton in the reign of James I. to supply London with water, runs through the county from north to south a little to the west of the river Lea. It derives its waters from the springs of Amwell and Chadwell, increased by a cut from the Lea, in the neighbourhood of Ware, and enters Middlesex from Hertfordshire about 2 miles north of Enfield. It passes Enfield, Tottenham, Hornsey, and Stoke Newington, and is received into the reservoir in Clerkenwell known as the New River Head.

The Grand Junction Canal leaves the Thames at Brent-

ford, proceeds in a westerly direction by way of Hanwell and Cranford to West Drayton; thence in a northerly direction it follows the valley of the Colne. It passes Uxbridge, and after leaving the county takes its further course by Rickmansworth through Hertfordshire. The Paddington Canal leaves the Grand Junction Canal at Cranford, and passes Northolt, Apperton, Twyford (where it is carried over the Brent by an aqueduct), and Kensal Green. At Paddington it joins the Regent's Canal, which passes the north of Regent's Park, and after proceeding through the eastern portions of London joins the Thames at Limehouse. The Regent's Canal is joined to the river Lea by means of Sir George Duckett's Canal, and thus there is a through communication from the north-eastern corner of the county to the south-eastern corner, thence from east to west, and northward to the north-west corner.

Climate, Soil, Agriculture, &c.—The climate of the county is equable and good, and the shelter of the northern hills makes the air mild. Highgate, Hampstead, and some other parts are supposed to be specially healthy, and are recommended for invalids by the medical profession.

The heavy poor clay in the north and north-western portion of Middlesex is chiefly covered with permanent grass. In some parts it has been made fit for arable cultivation by the addition of chalk, lime, and ashes. The rich deposits from the Thames have formed a soil which when well manured is specially suitable for market gardens. From its nearness to London the district has long been famous for high farming, and the divisions devoted to different kinds of farming are well marked. The greater part of Gore and Ossulston hundreds, portions of Spelthorne and Edmonton hundreds, and a strip down the western side of Elthorne hundred are devoted to meadow and pasture. The arable land is chiefly found on the western side, and between the Great Western Railway and the Thames. It is also to be seen in the north-western district. With the constant increase of London, houses have encroached upon the fields, and most of the market gardens which were situated in the neighbourhood of Islington and Hackney have disappeared. The strip of land by the Thames from Brentford to Chelsea was given up almost entirely to market gardens, but Fulham is fast being built over.

According to the returns for 1882, the area occupied by grain and green crops, grass, &c., was 116,470 acres. Of this amount, 16,337 acres were under corn crops (wheat, 6410; barley, 3083; oats, 3895; and beans and pease, 2636); 13,451 under green crops (including potatoes, 3019; turnips, 1539; mangolds, 1692; cabbage, &c., 1188); 3025 under clover and grasses sown in rotation; and 82,782 under permanent pasture. Orchards occupied 3419 acres; market gardens, 6900; nursery grounds, 447; and woods, 2382. In the same year the horses numbered 5939 (4188 used for agricultural purposes); cattle, 23,283 (cows, 15,390); sheep, 23,916; and pigs, 12,035.

The following were the landowners in the county (exclusive of London) at the time of the Domesday survey:—the king, the archbishop of Canterbury, the bishop and canons of London, the abbeys of Westminster and Holy Trinity at Caen, the nunnery of Barking, the Earls Roger and Morton, Geoffrey de Mannevele, Ernulf de Hesding, Walter Fitz Other, Walter de St Walery, Richard Fitz Gilbert, Robert Gernon, Robert Fafiton, Robert Fitz Roselin, Robert Blund, Roger de Rames, William Fitz Ansculf, Edmund de Salisbury, Aubrey de Vere, Ranulf Fitz Ilger, Derman, Countess Judith, and the king's almoners.

In 1873, according to the *Return of Owners of Land*, the total number of owners in the county (also exclusive of London) was 11,881, of whom 9006 owned less than an acre. The extent of lands (including common or waste lands) is given as 145,605. The gross estimated rental was £1,611,655. Sixteen owners each possessed over 1000 acres. The crown owned 2382 acres (annual value £5503); the duchy of Lancaster, 2273 acres (£4492); Ecclesiastical Commissioners, 1308 acres (£46,519); All Souls' College, Oxford, 1813 acres (£4724); Christ Church, Oxford, 1132 acres (£1635); and King's College, Cambridge, 1097 (£1084).

Many villages of Middlesex, especially those near to London, were formerly famous for their mineral springs. Some places are still supplied with water from wells; but the Barnet, the East Middlesex, the Grand Junction, the West Middlesex, and the New River Water Companies serve a large part of the county.

Manufactures and Trade.—There is little to remark with regard to the manufactures of the county outside of London. Brick-making and tile-making have always flourished, and malting, distilling, and soap-making are favourite industries. Gunpowder mills exist at Twickenham and Bedfont. The market-towns for corn are Uxbridge, Brentford, and Staines, for cattle and sheep Southall. A horse and cattle fair is held at South Mimms and Barnet.

Railways and Roads.—As London is the centre of the railway system of England, it is evident that many of the lines must run through Middlesex. For similar reasons it is well provided with roads.

Population.—The total population of Middlesex was 2,539,765 in 1871 and 2,920,485 in 1881, or excluding the seven metropolitan boroughs lying within the county 276,028 in 1871 and 394,089 in 1881. Most of the towns and villages have largely increased during the period between 1871 and 1881; the populations of Acton and Tottenham have more than doubled, and Chiswick, Ealing, Edmonton, and Willesden have almost doubled. Of the larger places the least increase has been at Brentford, which numbered 10,271 in 1871, and reached 11,808 in 1881. At the time of the Domesday survey the population of Middlesex, exclusive of London, was 2302.

Government.—Unlike other counties, Middlesex has no high sheriff appointed by the sovereign. It is subject to the City of London, and one of the sheriffs appointed by the lord mayor is sheriff for Middlesex. When Henry I. came to the throne he gave the city an extensive charter, and one of the privileges either granted or confirmed by the king was the perpetual sheriffwick of Middlesex.

The whole of the county is included in the diocese of London, and is divided between the archdeaconries of London and Middlesex. When Henry VIII. created the bishopric of Westminster he allotted the whole county (the parish of Fulham alone excepted) for its diocese. Edward VI., however, dissolved the bishopric in the fourth year of his reign.

The county is divided into six hundreds, which remain the same as they were at the time of the Domesday survey, except that the name of one has been changed:—Ossulston (Osulvestane D.), Edmonton (Delmetone D.), Gore (Gara D.), Elthorne (Heletorne or Helethorne D.), Spelthorne (Speletorne or Spelethorne D.), Isleworth (Honeslaw D., *i.e.*, Hounslow). The division into hundreds is now merely a name, and a record of a former system of local government.

There are thirty-two poor-law unions, but the unions beyond London are only eight in number, viz., Brentford, Edmonton, Fulham, Hackney, Hampstead, Hendon, Staines, Uxbridge.

The majority of hospitals are in London, but there is a training hospital at Tottenham, St John's Hospital at Twickenham, and cottage hospitals at Enfield, Ealing, Hayes, Hillingdon, Sudbury, and Teddington. The Royal India Lunatic Asylum is at Ealing, and the two county asylums at Colney Hatch and Hanwell.

The county is within the jurisdiction of the central criminal court and also of the metropolitan police (with the exception of the City).

Parliamentary Representation.—There are nine constituencies in Middlesex, returning nineteen members, viz., two for the county, four for the City of London, two for each of the boroughs of Westminster, Finsbury, Marylebone, the Tower Hamlets, Chelsea, and Hackney, with one for the university of London.

In the parliament of 1295 Middlesex was represented by two members; in 1298 London sent two members as well as the county. For the parliament of 1320 and subsequent parliaments London elected four members, but it does not appear that all were allowed to sit. From the 15th century, however, the city has always sent four members to parliament. In 1547 Westminster first sent her two members, and from that time until 1832 the only seats were those for the county and the two boroughs. In 1832 the boroughs of Finsbury, Marylebone, and Tower Hamlets were added, and in 1866 the boroughs of Chelsea and Hackney and the university of London.

History.—The district now included in Middlesex was largely occupied by forest up to a comparatively recent period, and its population must always have been very sparse. A few prehistoric remains have been discovered at various times,—bones of the elephant, hippopotamus, deer, &c., at Old Brentford, elk horns near Chelsea Hospital, fossil teeth, fish, fruit, &c., at Highgate, and quite recently, in 1879, while the foundations were being dug out for Drummond's New Bank at Charing Cross, a large number of prehistoric animal remains. Flint instruments have also been found to cover a considerable area. During the British period the district is supposed to have been inhabited by the Trinobantes, but

the late Dr Guest affirms that the valley of the Lea was the western boundary of that tribe. In answer to the question—What became of the district between the Lea and the Brent? this great authority states that the district was merely a march of the "Catuvellauni," a common through which ran a wide trackway, but in which was neither town, village, nor inhabited house. Dr Guest also declares that the boundaries of the Catuvellaunian state, a central kingdom formed or much extended by Cassivellaunus, can be traced in part along the northern limit of Middlesex by following an earthwork called Grimesditch "from Brockley Hill to the woodland of the Colne Valley and thence to the Brent, and down the Brent to the Thames."[1] Some earthworks and encampments still exist which are attributed to the Britons.

When the country was under Roman rule great improvements, due to the growing importance of Londinium, were made in this district. Several roads in connexion with the city must have been constructed, more especially the great northern and eastern roads. Dr Guest does not believe that the present Watling Street could have had any connexion with the Watling Street which came down the Edgeware Road, passed along by Park Lane, and crossed the Thames at Westminster. In the Antonine Itinerary mention is made of three stations, viz., Londinium, Sulloniacæ, and Pontes. Sulloniacæ is now Brockley Hill; Pontes is supposed by Stukeley to mean Staines, but Horsley held that it was intended for Old Windsor, and others supported the claims of Colnbrook and Longford. Roman camps have been found in many parts of the county, and Dr Stukeley supposed that the Brill, near St Pancras, was the site of the battle between Boadicea and the Roman legions which has left a slight record in the name of Battle Bridge. The Roman remains found at different times are too numerous to mention here in detail. Coins, urns, and tiles were found at Enfield, a sepulchral urn at Hampstead, and numerous gold coins and ornaments at Bentley Priory, Great Stanmore, in 1781.

Cowey Stakes, about a furlong west of Walton Bridge, is supposed to be the locality of the ford by which Julius Cæsar crossed the Thames. Cæsar makes special mention of the sharp stakes which he had to encounter, and Bede says that the remains of the stakes were to be seen in his day. Camden was the first to fix upon this as the spot where Cæsar crossed, and he is supported by Dr Guest, but the identification is not undisputed. Although a ford existed here as late as 1807, and stakes were found up to the end of the 18th century, it has been affirmed that they were placed in their position with another object than to oppose an enemy's progress. Roman remains have been found at Shepperton near Halliford, at the Middlesex end of the ford. A vase was dug up in 1817, and the remains of a Roman cemetery have also been discovered.

As to the earliest Saxon occupation we are left very much to conjecture, and the name itself is somewhat of a puzzle. It is evident that no tribe could have obtained the name of Middle Saxons until after the settlement of the districts on each side of it by the East and the West Saxons. As Middlesex was for a period dependent upon the kingdom of Essex, it is probable that the name did not come into use until London had become a Saxon city, although there is reason to believe that previously Saxon settlements had been made on several places by the river and elsewhere. Bede tells us that London was in the hands of King Sæberct in 604, and was then the chief town of Essex. Just a century afterwards—that is, in 704—the king of the East Saxons granted away land at Twickenham, showing that Middlesex was then dependent upon Essex. It is worthy of note that the two districts now forming the counties in which London and Southwark are situated were separated from the kingdoms to which they originally belonged probably on account of the importance of the city of London and the borough of Southwark, Middlesex from the kingdom of Essex and Surrey or the South Ridge (A.-S. Suð-rige) from the kingdom of Kent.

Middlesex appears never to have been independent. The administrative shire was let to the men of London and their heirs to be held in farm of the king and his heirs, and "the subject shire has to submit to the authority of the sheriffs chosen by the ruling city."[2]

Middlesex is only once mentioned in the Saxon Chronicle, under date 1011, where it is noticed as one of the districts overrun by the Danes. One manuscript (A. Winchester) mentions the Middle Saxons as receiving the true faith under their alderman Peada in 653; but this is evidently a mistake of the scribe, for the fact is taken from Bede, and he writes Middle Angles, as do the other MSS. of the Chronicle.[3]

The Saxons appear to have settled over a large portion of the district, and for the purpose of settlement they must have made considerable clearings in the vast forest of Middlesex. There seems to be good reason for believing that previous to their coming the roads passed through waste lands. By the time of Edward the Confessor a large proportion of the present towns and villages were in existence. Mr Elton, in his *Origins of English History*,[4] mentions a curious fact with relation to the tenures which prevailed in some of these places. He alludes to a ring of manors encircling ancient London where the custom of Borough English or junior right was prevalent.[5] He then goes on to point out that in this cluster of manors there are several varieties of the custom:—"Its benefit in Islington and Edmonton was confined to the youngest son; at Ealing, Acton, and Isleworth it extended to the brothers and male collateral heirs; and in a great number of instances the privilege was given to females as well as to males in every degree of relationship. These variations are of no very great importance, the custom being modified in all parts of the country by the rule that special proof must be given of any extension of that strict form of Borough English for the benefit of the younger son of which alone the courts have cognizance. But it is of the greater interest to observe that in several places near London 'it is the custom for the land to descend to the youngest, if it is under a particular value of five pounds, but if it is worth more, it is parted among all the sons' (*First Real Property Commission Evidence*, p. 254)."

The great forest of Middlesex continued long after the Norman Conquest, and even as late as the reign of Elizabeth portions of it still existed quite close to London. Fitz Stephen, the monk of Canterbury and secretary of Thomas a Becket, mentions in his interesting description of London the immense forest with its densely wooded thickets, and its coverts of game, stags, fallow deer, boars, and wild bulls. A few years after Fitz Stephen's death, in the reign of Henry III. (1218), the forest was disafforested, and some of the wealthy citizens took the opportunity of purchasing land and building upon it. Matthew Paris, in his life of the twelfth abbot of St Albans, describes the woods contiguous to the Watling Street between London and St Albans as almost impenetrable, and so much infested by outlaws and by beasts of prey that the numerous pilgrims who travelled along the Roman road to the shrine of Albanus were exposed to imminent danger.

There is little further history that can be told of Middlesex. There are many interesting incidents connected with some of the places, but corporate life has been crushed out of the county by the greatness of London. Not a single place except London has grown into importance, and nowhere outside of London is there a building of first-rate interest. The villages on the Thames early began to increase in size on account of the convenience of locomotion supplied by the river. It is only since the extension of the railway system that the villages to the north and north-west of London have grown in size, and this growth has been mainly due to the building of houses for the use of the Londoners.

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1 "Lecture on the Origin of London," *Athenæum*, 1866, No. 2022.

2 Freeman, *Norman Conquest*, vol. v. (1876) p. 468.

3 In the above passage from the Chronicle, where the districts overrun by the Danes in 1011 are enumerated, the shires, which took their names from their chief towns, are distinctly marked off from the districts which took their names from the peoples who inhabited them. Of the latter there are, besides the Middle Saxons, the East Angles, the Kentings, and the South Saxons. Middlesex is styled an administrative shire, because it was not historically a shire, but only one for the purposes of administrative organization. Of the present forty counties twenty-eight are and twelve are not shires. Wessex was divided into six shires, and Mercia into eighteen, with the subsequent addition of Rutland, taken (it is believed) from Northamptonshire. Yorkshire was taken from Northumbria, Lancashire from Cumbria, and, last of all, Monmouthshire from Wales, by an Act of Henry VIII.'s reign.

4 Pp. 188-89, and note.

5 Mr Corner gives the number of instances he has found at sixteen.

MIDDLETON, a market and manufacturing town of Lancashire, is situated on the Irk, near the Rochdale Canal, and on the Lancashire and Yorkshire Railway, about 5 miles north of Manchester and 4 west of Oldham. It includes the township of Tonge, an isolated portion of the parish of Prestwich. The church of St Leonards is an old structure of mixed architecture, with a low square tower. The oldest portion of the building dates from the 12th century, but the main portion from 1412, and the south aisle from 1524. It underwent extensive restoration in 1869. The Queen Elizabeth Grammar School, a building in the Tudor style, was founded in 1572. There are public baths and a free library. The prosperity of the town dates from the introduction of manufactures at the close of last century. The staple trade is the spinning and weaving of cotton, and the other industries include silk weaving, calico printing, bleaching, dyeing, ironfounding, and the manufacture of soap and chemicals. There are several collieries in the neighbourhood. The town was at an early period in possession of the Bartons, from whom it passed by marriage in the 16th century to Sir Ralph de Assheton. The population of the urban sanitary district of Middleton and Tonge in 1881 was 18,952.

MIDDLETON, Conyers (1683–1750), the earliest and most eminent example of the spirit of theological rationalism in the English Church of the 18th century, was the son of the rector of Hinderwell near Whitby, and was born at Richmond in Yorkshire, on December 27 (or, according to another account, on August 3), 1683. He graduated at Cambridge, took orders, and in 1706 obtained a fellowship, which he soon resigned upon contracting an advantageous marriage. In 1717 a dispute with Bentley, upon an extortionate demand of the latter on occasion of Middleton's being created D.D., involved him in an acrimonious controversy, which called forth several pamphlets from his pen full of powerful invective, and among them his first considerable literary performances, the *Remarks* and *Further Remarks* on Bentley's *Proposals for a New Edition of the Greek Testament* (1721). "You have laid Bentley flat upon his back," wrote Colbatch. "I scorn to read what the rascal has written," wrote Bentley,—who, however, only resorted to this affected disdain after a fruitless attempt to fix the authorship upon Colbatch, but who might justly have commented upon the impropriety of Middleton's endeavour to visit his grievances upon the text of the New Testament. Private resentment and uncurbed personality were throughout his life too frequently the motive and the note of Middleton's controversial publications. In 1723 he was involved in a lawsuit by personalities against Bentley, which had found their way into his otherwise judicious tract on library administration, written on occasion of his appointment to the honourable office of university librarian. In 1726 he gave great offence to the medical profession by a dissertation contending that the healing art among the ancients was only exercised by slaves or freedmen. Between the dates of these publications he visited Italy, and made those observations on the pagan pedigree of Italian superstitions which he subsequently embodied in his *Letter from Rome* (1729). This cogent tract, while establishing the author's main proposition with abundant learning and wit, gave at the same time the first clear indication of the anti-supernaturalistic bias of his intellect, and probably contributed to prepare the storm which broke out against him on his next publication (1731). In his remonstrance with Waterland on occasion of the latter's reply to Tindal's *Christianity as Old as the Creation*, Middleton takes a line which in his day could hardly fail to expose him to the reproach of infidelity. He gives up the literal truth of the primeval Mosaic narratives; and, in professing to indicate a short and easy method of confuting Tindal, lays principal stress on the indispensableness of Christianity as a mainstay of social order. This was to resign nearly everything that divines of the Waterland stamp thought worth defending. Middleton was warmly assailed from many quarters, and retreated with some difficulty under cover of a sheaf of apologetic pamphlets, and a more regular attendance at church. A freethinker in the strict sense of the term he certainly was; but how far freedom of thought was carried by him it is not easy to ascertain. His adversaries—some of them men who gravely maintained that Egyptian civilization originated in the age of Solomon—were unable to fix any serious imputation upon him; on the other hand it is clear that the natural attitude of his mind towards supernatural pretensions was one of suspicion, and that his temperament was by no means devout. That he was nevertheless not incapable of a disinterested hero-worship was evinced by his next important publication, the elegant but partial *Life of Cicero* (1741), a work which, if far below the standard of modern exactness, may yet compare in spirit and execution with the best productions of the Italian Renaissance. It is, indeed, as remarked by Forsyth, "rather an historical composition, in which Cicero is the principal figure, than the portrait of the man himself"; and Dr Parr has pointed out Middleton's unacknowledged obligations to the forgotten Bellendenus, which, however, with the ardour of a discoverer, he seems to have considerably overrated. The work was undertaken at the instance of Lord Hervey, in correspondence with whom also originated his disquisition on *The Roman Senate*, published in 1747. The same year and the following produced the most important of all his writings, the *Introductory Discourse* and the *Free Inquiry* concerning the miraculous powers then commonly deemed to have subsisted in the church after the apostolic age. In combating this belief Middleton indirectly established two propositions of capital importance. He showed that ecclesiastical miracles must be accepted or rejected in the mass; and he distinguished between the authority due to the early fathers' testimony to the beliefs and practices of their times and their very slender credibility as witnesses to matters of fact. Some individual grudge seems to have prompted him to expose, in 1750, Bishop Sherlock's eccentric notions of antediluvian prophecy, which had then been before the world for a quarter of a century. The same year he died of a decline at his seat at Hildesham in Cambridgeshire, leaving a widow, but no children.

Middleton's most ambitious work is obsolete from no fault of his, but his controversial writings retain a permanent place in the history of opinion. In his more restricted sphere he may not inappropriately be compared to Lessing. Like Lessing's, the character of his intellect was captious and iconoclastic, but redeemed from mere negation by a passion for abstract truth, too apt to slumber until called into activity by some merely personal stimulus. His diction is generally masculine and harmonious. Pope thought him and Hooke the only prose writers of the day who deserved to be cited as authorities on the language. Parr, while exposing his plagiarisms, heaps encomiums on his style. But his best qualities, his impatience of superstition and disdain of mere external authority, are rather moral than literary. As a scholar he is rather elegant than profound; as a controversialist he has more vigour than urbanity, and more wit than humour. He has been unjustly attacked both as author and as man by De Quincey, who strangely accuses his style of colloquialism, and taxes him with eating the church's bread while denying her doctrines. In fact Middleton's private means were ample, his ecclesiastical emoluments trifling, and his candour obstructed his path to much more considerable preferment. The best general view of his intellectual character and influence is to be found in Leslie Stephen's *English Thought in the Eighteenth Century*, chap. vi. A handsome edition of his works, containing several posthumous tracts, but not including the *Life of Cicero*, appeared in 1752.

MIDDLETON, Thomas (*c.* 1570–1627), held a leading place among the dramatists of the reign of James I. His

popularity would seem to have first come to a height about 1607. This is a fair inference from the fact that in this and the following year a whole swarm of comedies from his pen were licensed and published—*A Trick to Catch the Old One*, *The Family of Love*, *The Phœnix*, *Michaelmas Term*, *Your Five Gallants*, *A Mad World My Masters*. Only the first of these kept the stage after the author's own generation, though in point of wit and constructive skill it is not superior to *The Phœnix* (a serious comedy) or *Your Five Gallants* (a bustling and gaily humorous farcical comedy). The plot of the *Trick* bears a family likeness to that of Massinger's *New Way to Pay Old Debts*; the titles in fact might be interchanged. A ruined scapegrace outwits his creditors and a usurious uncle by coming to town with a courtesan and passing her off as a widow with a fortune, whom he treats with deferential friendship, but hardly dares to love, ruined and hopeless as he is. His uncle lends him money that he may woo in proper state; his creditors also intrigue to have the honour of supplying him with all the needs of fashion; and the lady receives many costly presents from aspirants to her hand and fortune. Though Middleton was apparently not in high popularity till 1607, he had made his debut as a satirist ten years before; and if Malone is right in his conjecture that the *Mayor of Queensborough* is identical with the *Randall Earle of Chester* mentioned by Henslowe in 1602, he had done dramatic work of a much higher kind. Like *The Changeling*, a later production, in which Middleton had the assistance of Rowley, the tragedy of the *Mayor* is named after a character in the insignificant comic underplot. Such a title scares away readers weary of half-intelligible Elizabethan fun and satire; but Simon the comic mayor is a very subordinate figure in the play, and the tragic portions alike in situation, characterization, and language rank among the very noblest productions of the Shakespearian age. There are scenes in the *Changeling* also which Mr Swinburne, with a judgment that will not be disputed, assigns to Middleton, unsurpassed for intensity of passion and appalling surprises in the whole range of Elizabethan literature. The execution of these scenes is far beyond any power that Rowley showed in single-handed work, but well within the scope of the author of the *Mayor of Queensborough* and *Women Beware Women*. This last play, in which every one of the characters important enough to be honoured with a name perishes at the end in a slaughter so rapid as to be somewhat confusing, was apparently one of Middleton's later works, and the simple and measured development of the plot in the first acts seems to show traces of the influence of Massinger. Middleton's verse, when charged with the expression of impassioned love, contains many echoes of the verse of *Romeo and Juliet*, as if his ear had been fascinated by it in his youth. His language generally proclaims him an admiring disciple of Shakespeare's; and in daring and happy concentration of imagery, and a certain imperial confidence in the use of words, he of all the dramatists of that time is the disciple that comes nearest the master. *The Witch*, by which Middleton's name has of late been linked with Shakespeare's in groundless speculation as being part author of *Macbeth*, is by no means one of Middleton's best plays. The plot is both intricate and feeble, as if the play had been written with a view to the half-comic spectacular exhibition of the witches, with their ribald revelry, their cauldrons, hideous spells, and weird incantations. Charles Lamb's comparison of Middleton's witches with Shakespeare's is one of the most exquisite morsels of criticism; but, when he says that Middleton's witches are "in a lesser degree fine creations," he ought perhaps to have added that they are merely embodiments of the vulgar superstition, put on the stage to excite laughter rather than fear among a half-believing audience, an audience ready to laugh at them in the light and in a crowded meeting, whatever each might do in the dark alone. That Middleton had any share in *Macbeth* is a conjecture resting solely on the fact that the opening words of the song of the witches about the cauldron in Shakespeare's *Macbeth* occur also in the incantations about a cauldron in the last act of Middleton's *Witch*, and that Middleton's song was inserted by Davenant in an "amended" reproduction of *Macbeth*. If either borrowed the words of this song from the other, that is no evidence of further co-operation; besides all that is common to the two was probably as much public property as a nursery rhyme. There is no evidence as to whether *The Witch* appeared before or after *Macbeth*. Middleton co-operated with Dekker in the *Roaring Girl*; with Rowley in *A Fair Quarrel*, *The Spanish Gipsy*, and *The Changeling*; and with Jonson and Fletcher in *The Widow* (one of the few of Middleton's plays reproduced after the Restoration). Towards the close of his life Middleton got into difficulties with the privy council from writing a very clever political play apropos of Prince Charles's unsuccessful wooing of the Spanish infanta in 1623. The chief personages in Spanish politics and their manœuvres were represented with most ingenious skill in the pieces and movements of *A Game at Chess*. This play was stopped by royal authority, and the prosecution of the author was allowed quietly to drop. The few unimportant facts known in Middleton's private history are collected in Mr Dyce's admirable edition of his plays. He enjoyed the office of city chronologer, and was often employed to write pageants and masques, in one case at least contracting for the whole exhibition, besides furnishing the words. He died in 1627, and was buried at Newington Butts.

MIDDLETOWN, a city and port of entry of the United States, and one of the shire towns of Middlesex county, Connecticut, lies on the right bank of the Connecticut river, about 30 miles from its mouth, directly opposite the well-known Portland quarries, and 24 miles from New Haven by rail. Built on ground rising gently from the river, with its principal streets keeping the direction of the valley, and the cross streets climbing the slope, Middletown is a place of considerable attractiveness, and the views from the higher points are particularly fine. Water Street, with the wharves and shipping, Main Street, with the commercial houses and hotels, and High Street, with its mansions and gardens and trees, are the leading lines of the city. On the high grounds behind stand the handsome buildings of the Wesleyan (Methodist Episcopal) University. The institution, mainly organized by Wilbur Fisk, D.D., was chartered in 1831. To the two buildings with which it started have been added Rich Hall, with the library of about 30,000 volumes, Judd Hall, with scientific collections of great value, the Memorial Chapel, erected in the centenary year of American Methodism, and the Observatory Hall. Since 1872 the courses of the university have been open to both sexes. In 1882 the number of professors was 20, and of students 191, including 14 females. The Berkeley Theological School (Main Street), founded by the Episcopal Church in 1854, had in 1882 7 professors and 41 students, with a library of 17,000 volumes. A hill 1¼ miles to the south-east of the city is occupied by the State General Hospital for the Insane, the principal building having a frontage of 768 feet, and the grounds extending to 230 acres; and on another hill to the south-west of the city stands the State industrial school for girls. As vessels drawing 10 feet of water can reach its wharves, Middletown carries on a considerable trade by the river. In 1882 1613 vessels, with a burden of 240,000 tons, entered the port, and 1613 vessels, with a burden of 350,000 tons,

cleared; and the Middletown district owned 83 sailing vessels and 22 steamers. Both the silver and the lead mines which were formerly worked in the vicinity have been abandoned, but cast-iron, britannia, and silver-plated goods, sewing-machines, pumps, webbing, and tape are among the local manufactures. The population of the city increased from 5182 in 1860 to 6850 in 1880. First settled in 1636, Middletown was incorporated as a town in 1654, and as a city in 1784.

MIDDLETOWN, a manufacturing village of the United States, in Wallkill township, Orange county, New York, 55 miles N.N.W. of New York, at the junction of four railroads. It is a clean well-built place, in the midst of a fine dairy-farming and stock-raising district, manufactures saws, files, felt hats, blankets, agricultural implements, printers' materials, &c., and is the seat of the State Homœopathic Insane Asylum. The population was 6049 in 1870 and 8494 in 1880.

MIDHURST, an ancient parliamentary borough and market-town of Sussex, is picturesquely situated on a gentle eminence above the south bank of the West Rother, on three railway lines, 50 miles south-west of London and 12 north from Chichester. The church of St Denis (restored in 1881–83) is chiefly Perpendicular in style, but the lower part of the embattled tower is probably Norman. At the grammar school, founded in 1672, Richard Cobden and Sir Charles Lyell were educated. A new public hall was opened in 1882. The old castle of the De Bohuns stood on a mound above the river, now overgrown with trees. In ancient times a commandery of the Knights of St John of Jerusalem had jurisdiction over the district now forming the liberty of St John. The prosperity of the town depends chiefly on agriculture. A market is held weekly, and a fair three times a year. The population of the parliamentary borough, which has an area of 26,172 acres, was 6753 in 1871, and 7221 in 1881.

Midhurst is not mentioned in Domesday, being included under Easebourne. In the reign of Henry I. it was held by the king as a minor barony. In the time of Edward I. it passed into the possession of the De Bohuns. From the time of Edward II. till 1832 it returned two members to parliament, but since then only one.

MIDIAN was one of the peoples of North Arabia whom the Hebrews recognized as distant kinsmen, representing them as sons of Abraham's wife Keturah. The word Keturah means "incense"; thus the sons of Keturah are the "incense-men," not indeed inhabitants of the far south incense-land, but presumably the tribes whose caravans brought the incense to Palestine and the Mediterranean ports. So the Midianites appear in connexion with the gold and incense trade from Yemen (Isa. lx. 6), and with the trade between Egypt and Syria (Gen. xxxvii. 28, 36). At the time of the exodus the pastures of the Midianites, or of the branch of Midian to which Moses's father-in-law (Jethro or Raguel, or Hobab) belonged, lay near Mount Horeb (Exod. iii. 1); and Num. x. 29 *sq.* implies that the tribe was at home in the desert of the wanderings. The Kenites, who, in spite of their connexion with Amalek (1 Sam. xv. 6), had friendly relations with Israel, and ultimately coalesced with the tribe of Judah, are represented in Judg. i. 16, iv. 11 as the kin of Moses's father-in-law. The Kenites, however, can have been but one fraction of Midian which took a separate course from their early relations to Israel.[1] The main body appear in Judg. vi. as a powerful Bedouin confederation, invading Canaan from the eastern desert, and ravaging the land as similar tribes have done in all ages when Palestine lacked a strong government. With their defeat by Gideon and another defeat by the Edomites in the field of Moab, probably about the same time (Gen. xxxvi. 35), the recorded history of Midian closes.

A place Midian is mentioned 1 Kings xi. 18, and in later times the name lingered in the district east of the Gulf of 'Akaba, where Eusebius knows a city Madian in the country of the Saracens and Ptolemy places Modiana. Still later Madyan was a station on the pilgrim route from Egypt to Mecca, the second beyond Aila (Elath). Here in the Middle Ages was shown the well from which Moses watered the flocks of Sho'aib (Jethro), and the place is still known as "the caves of Sho'aib." It has considerable ruins, which have been described by Rüppell (*Reisen*, 1829) and Burton (*Land of Midian*, 1879).

[1] The admixture of Midianite elements in Judah and the other border tribes of Israel is confirmed by a comparison of the names of the Midianite clans in Gen. xxv. 4 with the Hebrew genealogies (1 Chron. ii. 46, iv. 17, v. 24; Gen. xlvi. 9)

MIDNAPUR, a district in the lieutenant-governorship of Bengal, India, between 21° 37′ and 22° 57′ N. lat., and between 86° 35′ 45″ and 88° 14′ E. long., is bounded on the N. by Bánkurá and Bardwán, on the E. by Hooghly and Howrah, on the S. by the Bay of Bengal, and on the W. by Singbhúm and Mánbhúm, with an area of 5082 square miles. Its general appearance is that of a large open plain, of which the greater part is under cultivation. In the northern portion the soil is poor, and there is little wood. The country along the western boundary, known as the Jungle Mahals, is undulating and picturesque; it is almost uninhabited. The eastern and south-eastern portions are swampy and richly cultivated. The chief rivers of the district are the Hooghly and its three tributaries, the Rúpnáráyan, the Haldi, and the Rasulpur. The Midnapur high-level canal runs almost due east and west from the town of Midnapur to Ulubariá on the Hooghly 16 miles below Calcutta, and affords a continuous navigable channel 53 miles in length. There is also a tidal canal for navigation, 26 miles in length, extending from the Rúpnáráyan river. The jungles in the west of the district yield lac, *tasar* silk, wax, resin, firewood, charcoal, &c., and give shelter to large and small game.

The census of 1872 returned the population of Midnapur at 2,540,963 (1,257,194 males and 1,283,769 females), including only 122 Europeans and 157,030 Mohammedans. The aboriginal tribes belong chiefly to the jungles and hills of Chutiá Nágpur and Bánkurá; the most numerous of them are Santáls (96,921) and Bhumíjs (35,344). Of high-caste Hindus the returns show 136,500; and the number of Káyasths is given as 101,663. Among the semi-Hinduized aborigines, the most numerous are the Bágdis, a tribe of cultivators, fishermen, and day-labourers (76,825). Belonging to agricultural castes there are 1,018,686. The four municipalities are Midnapur (31,491), Chandrakona (21,311), Ghatal (15,492), and Tamlúk (5849). Rice is the staple crop. Irrigation is effected chiefly from the high-level canal. Rent rates vary from 10½d. an acre for the poorest quality of rice land to 18s. an acre for the best irrigable lands. The district suffers occasionally from drought; floods are common, and very disastrous in their results. The principal exports are rice, silk, and sugar; and the chief imports consist of cotton cloth and twist. Salt, indigo, silk, mats, and brass and copper utensils are manufactured. Apart from the rivers, communication is afforded by 482 miles of road. The total revenue in 1870–71 was £262,578, and the expenditure £53,777. The prevailing diseases are fever, diarrhœa, dysentery, and cholera. The average mean temperature is 80° Fahr., and the average annual rainfall 66 inches.

The early history of Midnapur centres round the ancient town of Tamlúk, which in the beginning of the 5th century was an important Buddhist settlement and maritime harbour. The first connexion of the English with the district dates from 1760, when Mír Kásim ceded to the East India Company Midnapur, Chittagong, and Bardwán (then estimated to furnish one-third of the entire revenue of Bengal) as the price of his elevation to the throne of Bengal on the deposition of Mír Jafar.

MIDNAPUR, chief town and headquarters station of the above district, is situated on the north bank of the Kasái river, with a population in 1872 of 31,491. The town has a large *bázár*, with commodious public offices. It is healthy, dry, and well supplied with water. An American mission maintains an excellent training school, together with a printing press, and has founded several village schools in

the district. Its efforts have been particularly successful among the Santáls, and some of the earliest and most valuable works on their language have issued from the Midnapur mission press. A brisk manufacture of brass and copper utensils takes place in the town; it is also the centre of a large indigo and silk industry.

MIDRASH. Like all nouns of a similar form *Midrash* is the equivalent of the Niph'al participle,[1] and as such yields as many modified meanings as the root *Darosh* (דָּרַשׁ), to search, &c., itself has. The practical significations, however, of *Midrash*, taken in historical order, are as follows:—(1) a book of records; (2) a recension of older, especially historical, materials; (3) search in and explanation of the Scriptures, notably the Pentateuch (in which case the plural is invariably *Midrashoth*); (4) theory as distinguished from practice; (5) a college for study and teaching; (6) an *Agadic* (that is, a free) explanation, in contradistinction to an *Halakhic* one; (7) a collection of such free explanations (in which case the plural is *Midrashim* and occasionally also *Midrashoth*). Of these seven significations (1) and (2) are to be found in the Bible,[2] (3) and (4) are mentioned for the first time in the *Mishnah*,[3] (5) is to be met with in the *Midrash*,[4] while (6) and (7) are to be found in early Rabbinic writings.[5]

The subject of this article will be—(1) the nature of *Midrash* in the sense of *Agadah*, to the exclusion of *Halakhah* (for which see MISHNAH), and (2) the development of this *Midrash Agadah* into books (*Midrashim*).

The thinking reader of the Scriptures cannot have failed to observe that by the side of their ceremonial element, be it negative or affirmative, permissive or jussive, there is also often to be met with (and sometimes so as to be inseparable from it) a spiritual element. This spiritual element rests chiefly on feeling or emotion, and produces pious works only indirectly. Now the explanation or application of this element, either by the Scriptures themselves or by the rabbis, is traditionally called *Midrash Haggadah* (recitation, preaching) or *Midrash Agadah*[6] (binding the soul to God and all that is godly).

This *Haggadah* or *Agadah* varies considerably both in nature and form. In its nature it sometimes humours, at other times threatens; it alternately promises and admonishes, persuades and rebukes, encourages and deters. In the end it always consoles, and throughout it instructs and elevates. In form it is legendary, historical, exegetic, didactic, theosophic, epigrammatic; but throughout it is ethical.

And varied as was and is the *Midrash Agadah*, so varied have been its fortunes. Whilst at times it stood very high in the estimation both of the teachers and the congregations in Israel,[7] it sank at other times very low indeed.[8] Nay, at one and the same time, whilst some rabbis exalted it to the skies,[9] other rabbis treated it with hatred,[10] or, worse still, with contempt.[11] There have actually been teachers whose treatment of it differed with the difference of the occasion.[12] The fact is the Jews liked or disliked the *Midrash Agadah* according to their political condition on the one hand and their proximity to Jewish professors of Christianity on the other. In the hour of prosperity the Jews preferred the *Halakhah*;[13] in that of adversity they ran to hear the consoling words of the *Agadah*.[14] When near Judæo-Christians, whose religious strength and argument chiefly rested on *Agadah*,[15] the Jews disliked it; when among themselves, or when dwelling among Gentiles (heathen or Christian), they showed their wonted partiality for it.

But, whatever were the likings or dislikings of the Jews for the *Midrashoth*, it is certain that these traditions were early[16] committed to writing, and formed into special volumes, known as "Books of *Agadah*."[17] Such were first some of the *Targumim* and then the *Midrashim*. Against writing down the traditional explanations of the Mosaic ceremonial there existed a distinct law,[18] which was observed down to near the end of the 6th century. At an earlier period isolated disciples only, in order to refresh their memory, wrote down short Halakhic notes, which, however, they kept in secret.[19] The *Targumim* and *Midrashim*, on the other hand, were composed very early and were numerous, while their extensive contents were circulated in public.

The *Midrash*, from whatever point of view it may be regarded, is of the highest value. It is of the highest value, of course, to the Jew as Jew first, inasmuch as he finds there recorded the noblest ideas, sayings, and teachings of his venerable sages of early times. In the next place it has value to the Christian as Christian, since only by these ideas, teachings, reasonings, and descriptions can the beautiful sayings of the Founder of Christianity, the reasonings of the apostles, and the imagery of the sublime but enigmatic Apocalypse be rightly understood. But its importance appeals also to the general scholar, because of the inexhaustible mines of information of all kinds it contains. The philologist will find here numerous hints on lexicography and grammar, chiefly, of course, of the Semitic languages, but also of other tongues, notably Greek and Latin. The historian will gather here a rich harvest on geography, chorography, topography, chronology, numismatics, &c. The philosopher will find here abundant and

[1] Comp. Nehem. viii. 8, where במקרא evidently stands for בנקרא. See also Kimhi on 2 Chron. xiii. 22, and Schiller-Szinessy, *Exposition*, &c., Cambridge, 1882, p. 11.

[2] 2 Chron. xiii. 22 and xxiv. 27.

[3] See *Nedarim*, iv. 3, and *Aboth*, i. 17.

[4] *Bereshith Rabbah*, c. lxiii. (on Gen. xxv. 22): והלא לא הלכה אלא למדרשו של (שם ו)עבר... *Midrash* is used in the East to this day for *Beth Hammidrash*. See MS. Oo. 6, 63 (of the University Library, Cambridge), leaf 135*a*, lower margin (והם קדש למדרשו של שם...).

[5] Rashi (*e.g.*, on Gen. iii. 8) and *Tosaphoth*, *passim*.

[6] Those who identify this word as merely the Chaldaic form of the Hebrew *Haggadah* (and they have, certainly, some authority on their side) ought to write it *Aggadah* (אַגָּדָה), which, however, is not the traditional spelling of it (אֲגָדָה). Singularly enough, the Latin *religio* is similarly derived by some from *religare* and by others from *religere*.

[7] *Siphere* on Deut. § 49: "If thou wishest to know Him who but spake and the world came into being, learn *Haggadah*; for by so doing thou wilt recognize the Holy One (blessed be He!) and cling to His ways!"

[8] T. Y., *M'aseroth*, iii. 4: "And R. Ze'erah was teasing those rabbis of the *Agadah*."

[9] *Ibid.*: "Then said to him R. Bo bar [son of] Kohano, Why dost thou tease them? Ask, and they will surely answer thee!"

[10] T. Y., *Shabbath*, xvi. 1: "He who holds it forth becomes burned by it; he who listens to it gets no reward."

[11] *Ibid.*: "I never in my life looked into Agadic books."

[12] *Ibid.*: "Let the hand of him who wrote it be cut off"; and compare with this T. B., *Bobo Bathro*, 123*b*: "goodly pearl."

[13] Beginning of *Pesiḳotho Baḥodesh Hasshelishi*: "First when the money was at hand one desired to hear the word of the *Mishnah* and the word of the *Talmud*. . . ."

[14] *Ibid.*: "Now, however, when the money is not to be got, and, moreover, when we are sick in consequence of the (treatment by the) government, one pines for the word of the Bible and for the word of the *Agadah*."

[15] T. Y., *Shabbath*, xvi. 1, and T. B., *Shabbath*, 116*a*: "The *Evangelia* and other Christian writings."

[16] See *Tosephto Shabbath*, xiv.: "I remember that one brought before Rabban Gamliel the elder [St Paul's teacher] the book of Job (in the) Chaldaic paraphrase"; and T. Y., *Kilayim*, ix. 4: "At that time I ran (my) eyes through the whole Book of the Psalms (in the form) of the *Haggadah* [*Agadah* of the Psalms]." R. Ḥiyya *Rubboh* belonged to the middle of the 2d Christian century.

[17] ספרי דאגדתא. See T. B., *Berakhoth*, 23*a*, *Temurah*, 14*b*, and the *Talmudim*, *passim*.

[18] T. B., *Gittin*, 60*b*: "In the college of R. Yishm'ael it was taught, 'These [see Exod. xxxiv. 27] thou oughtest to write down, but thou must not write down *Halakhoth*.'"

[19] T.B., *Shabbath*, 6*b*: "I found a 'secret roll,'" that is, a roll of *Halakhoth* kept secret. Comp. Rashi, *in loco*.

valuable notices on logic, psychology, metaphysics, theology, theosophy, æsthetics, rhetoric, poetry, mathematics, geometry, astronomy, zoology, botany, biology, morphology, chemistry, medicine, physics, &c. The statesman—particularly if he be inclined to follow the Psalmist's advice—"from the ancients I gather understanding" (cxix. 100)—will find here valuable information on ancient ethnography in the full sense of the term—politics, political economy, law, military science, naval affairs, &c. The true scholar will find out by the study of the *Agadah* that many a discovery thought to belong to a recent age was well known to these ancient doctors.

The sources of the *Agadah* are five:—(1) the *Targumim* and especially those on the Prophets and Hagiographa; (2) the non-canonical *Mishnah* (*Mathnitho Boraitho*; see MISHNAH), which contains many valuable pieces, the age of which is often anterior, in essence if not in form, not only to those contained in the canonical *Mishnah*, but also to the sayings of the New Testament; (3) the canonical (officially recognized) *Mishnah*, which contains several entire treatises of an *Agadic* nature, as *Aboth*,[1] *Middoth*, &c.,[2] and numerous pieces scattered here and there among the *Halakhah*; (4) both *Talmudim*[3] (the Palestinian and Babylonian), which have thousands of Agadic notices interspersed in their *Halakhoth*; and (5) the *Midrashim*, κατ' ἐξοχήν. It is of the last alone, as represented by their principal collections, that we give an historical enumeration here:—

(1) *Megillath Ta'anith* is an historical *Midrash* consisting of twelve *Peraḳim*, and is called so on the principle of *lucus a non lucendo*, seeing that in it are enumerated the days of the year on which a Jew must not fast. The Aramaic part of it alone constitutes the real *Megillah*, and belongs to the beginning of the 2d Christian century.[4] The *editio princeps* came out at Mantua, 1513, 4to; but cheap editions have been printed at Warsaw and elsewhere.

(2) *Sepher Yeẓirah* is a philosophico-cabbalistic *Midrash* divided into six *Peraḳim*, which, in their turn, are subdivided into *Mishniyyoth*. It is variously ascribed to the patriarch Abraham and to R. 'Aḳibah, the illustrious teacher, who suffered martyrdom under Hadrian. To this rabbi the book, no doubt, belongs both in substance and form.[5] It has gone through numerous editions, the *ed. princ.* being of 1562 (Mantua, 4to), and has been translated into Latin, German, and English (New York, 1877).

(3) *Othiyyoth de-Rabbi 'Aḳibah* is a *quasi*-cabbalistic *Midrash* on the alphabet, belonging, in essence if not in form, to the aforesaid teacher and martyr. *Ed. princ.*, Constantinople, 1520, 4to.

(4) *Massekheth Hekhaloth* is an astronomico-cabbalistic *Midrash* in seven *Peraḳim*. It is ascribed to R. Yishma'el the high priest. Judging from internal evidence on the one hand, and from what is known of R. Yishma'el in the *Talmudim* and *Midrashim* (*Babli Berakhoth*, 7*a* and elsewhere) on the other hand, there seems to be no valid reason for doubting that he is the author of this small but sublime book. This *Midrash* is printed in the collection *Arze Lebanon* (Venice, 1601, 4to) under the title of "*Pireḳe Hekhaloth*" and "*Massekheth Hekhaloth*," and a MS. of it is preserved in the University Library of Cambridge (Dd. 10. 11. 7. 2). The work, however, called "The Greater and the Lesser *Hekhaloth*," in thirty *Peraḳim*, printed in this century, somewhere in Poland, contains, besides the ancient literature, a good deal of matter which is of much later date.

(5) *Seder 'Olam* (the Greater and the Lesser) are two historical *Midrashim*, the former of which belongs to the 2d century, whilst the latter (which is a mere extract of the former) belongs to a late age indeed (the Gaonaic). They have been repeatedly printed, always together, the *ed. princ.* being Mantua, 1513, 4to.

(6) *Haggadah shel Pesaḥ* is a liturgical *Midrash* of the middle of the 2d century, as far as its main portions go. It exists now in three principal and several minor recensions in accordance with the various rituals (see MAḤZOR), and is recited at the domestic service of the first two Passover evenings. The editions are too numerous to be mentioned, the *ed. princ.* being Constantinople, 1505, folio.

(7) *Megillath Antiokhos* treats ostensibly, as its name indicates, of the sufferings of the Jews under Antiochus Epiphanes, and their deliverance from his tyranny, but in reality of their sufferings under Hadrian and their deliverance under Antoninus Pius. The Aramaic text, with the exception of a few interpolations, belongs to the middle of the 2d century. This little "roll" was for the first time published by Filipowsky (London, 1851, 32mo). A MS. copy of the Hebrew is preserved in the University Library of Cambridge (Dd. 8. 34).

(8) *Zohar* (*Midrash Hazzohar*, *Midrasho shel Rabbi Shim'eon b. Yoḥai*, *Midrash Yehi Or*, &c.) is a cabbalistic *Midrash* on the Pentateuch, Canticles, Ruth, and part of Lamentations. It is variously ascribed to the famous R. Shim'eon (disciple of R. 'Aḳibah, &c.) and to R. Mosheh b. Shemtob of Leon (a second-rate cabbalist of the time of Naḥmanides and Ibn Addereth). The *Zohar* belongs, strictly speaking, to neither of these, whilst, in a certain sense, it belongs to both. The fact is—the nucleus of the book is of Mishnic times, and R. Shim'eon b. Yoḥai was the author of the *Zohar* in the same sense that R. Yoḥanan was the author of the Palestinian Talmud, *i.e.*, he gave the first impulse to the composition of the book. But R. Mosheh of Leon,[6] on the other hand, was the first not only to copy and disseminate the *Zohar* in Europe, but also to disfigure it by sundry explanatory interpolations. For more details see Lumby, "Introduction to the Epistle of Jude," in the *Speaker's Commentary*, vol. iv. p. 388. The first two editions of the *Zohar*[7] on the Pentateuch came out simultaneously (Mantua, 1558–60, 4to, and Cremona, 1558, folio), and the *ed. princ.* on Canticles, Ruth, and part of Lamentations came out at Salonika (1597, 4to). The best, though by no means critical, edition on the Pentateuch is that of Brody, 1873, 8vo. Of translations, such as they are, there exist those of Knorr v. Rosenroth, *Kabbala denudata* (vol. i., Sulzbach, 1677, and vol. ii., Frankfort, 1684, 4to), and Tholuck, *Wichtige Stellen*, &c. (Berlin, 1824, 8vo), &c.[8]

(9) *Pesiḳotho*[9] (commonly, but by mistake, called *Pesiḳta*) *derab Kohano* is a homiletic *Midrash* consisting of thirty-two *Pesiḳtoth* for the principal festivals and fasts, and the historically noted sabbaths and other days. It is of the end of the 3d or the beginning of the 4th century. Having been but rarely quoted since the 12th century, so that most scholars knew of it only

[1] A valuable edition of this treatise (in Hebrew and English) has been published by Dr C. Taylor, Cambridge, 1878.

[2] To these we may add, for the sake of convenience, although they do not, strictly speaking, belong to the canonical *Mishnah*, the *Pereḳ Rabbi Meir* and the Agadic parts of the *Massekhtoth Ketannoth*.

[3] Two collections of Talmudic *Agadoth* were made early in the 16th century:—(1) *Haggadoth Hattalmud*, Constantinople, 1511, folio, of which apparently only five copies are in existence, the finest of these being preserved in the University Library of Cambridge; and (2) *'En Ya'akob* (or *'En Yisrael*), of which numerous and cheap editions exist, the *ed. princ.* being that of Salonika, 1516–22.

[4] Almost all that the latest critics have said concerning the age of the various *Targumim* and *Midrashim* will have to be unsaid. Not only are negative statements difficult of proof; in this case they are absolutely incorrect. We shall only give two examples. The statement "*Vayyiḳra Rabbah* cannot be early, as Rashi did not know of it, since he nowhere mentions it," is doubly incorrect: Rashi *does* quote it (*e.g.*, on Haggai i. 1). Again the statement "We must not omit to observe that no early Jewish commentator—Rashi, Ibn Ezra, &c.—mentions the Targum either to Proverbs or to Job and Psalms; Nathan ben Jechiel (12th century) is the first who quotes it," contains a *reductio ad absurdum* in itself. For Nathan b. Yeḥiel was, as is well known, a somewhat older contemporary of Rashi (*ob.* 1105), and lived full a hundred years before Ibn 'Ezra!

[5] See T. B., *Synhedrin*, 65*b* and 67*b*. In the former place it distinctly speaks of the *Sepher Yeẓirah* (ספר יצירה), and, although in the latter place it speaks of the *Hilckhoth Yeẓirah* (הלכות יצירה), there cannot be a doubt that *Sepher* (ספר) and *Hilekhoth* (הלכות) are there identical. Moreover, *Mishniyyoth* and *Halakhoth* are, in a certain sense, convertible terms (see MISHNAH); and our book (as remarked above) consists of *Mishniyyoth*.

[6] R. Mosheh of Leon is a fair sample of the mediocrity of his time in cabbalistic lore, and combined, as is usual, with his mediocrity an illimitable vanity; see MS. Dd. 11. 22 (Cambridge University Library), leaf 2*a*: "And I adjure every one who should deeply study this book, or who should copy it, or read it, that he do not blot out my name from my property (inheritance), for I have composed it. . . ." This statement alone would suffice to prove that R. Mosheh of Leon could never have ascribed a book composed by himself to anybody else.

[7] The *Zohar*, cleared of the main works by which it is surrounded, and of the interpolations by which it has been disfigured both by its first European copyist and by others down even to our own days, was begun in Palestine late in the 2d or early in the 3d century, and finished, at the latest, in the 6th or 7th century. It is impossible that it should have been composed after that time and before the Renaissance, as both language and contents clearly show.

[8] Whilst the principal editions of the many textual extracts made from the *Zohar* (as the *Idd'oth*, &c.) need not be specified here, those of the following supplementary and kindred works ought to be mentioned:—(1) *Tiḳḳune Hazzohar* (*ed. princ.* Mantua, 1557, 4to), and (2) *Zohar Ḥadash* (*ed. princ.* Cracow, 1603). Nor should the *Kontres missepher Hazzohar*, *Ḥibburo Tinyono* (by the otherwise very learned Yitshaḳ b. Mosheh of Satanow) be passed over. It is a mere imitation of the *Zohar*,—an imposition of a kind which is a disgrace to literature.

[9] For the three *Midrashim*—*Mekhilto*, *Siphro*, and *Siphere*—see under MISHNAH.

indirectly, it was long considered lost, till, in 1868, Salomon Buber of Lemberg, a man of learning, wealth, and love for the ancient literature of his nation, edited it from four MSS., one of which (formerly in possession of Carmoly) is now preserved in the University Library of Cambridge (Add. 1497). The printed edition appeared at Lyck, 8vo.

(10) *Pesikto Rabbathi*, consisting in the latest edition of eighty-four *Piskoth*, is a *Midrash* of the same nature, and, in its main part, almost of the same date, as (9). Both drew from the same sources. This *Midrash* has been edited five times,—the latest, best, and cheapest edition being that of Friedmann (Vienna, 1880, 8vo).

(11) *Tanna debe Eliyyahu* consists of two parts, the Greater (Rabbo) and the Lesser (Zutto),—the former in thirty-one and the latter in twenty-five *Perakim*. It is an exegetical *Midrash*, the name of which is already known to the *Bereshith Rabbah* (c. liv.) and the Babylonian Talmud (*Kethuboth*, 106*a*). It is only uncritical criticism that can declare it a Gaonaic work, although, like all other old books of the Jews, it is not without later additions. *Ed. princ.*, Venice, 1598, 4to. There are modern and cheap Polish editions.

(12) *Midrash Rabbah* (רבה) or *Rabboth* (רבות) is chiefly an exegetical and homiletical *Midrash* on the Pentateuch and the "Five Rolls" (*Hamesh Megilloth*; *i.e.*, Canticles, Ruth, Lamentations, Ecclesiastes, and Esther). It is called *Rabbah* either from the third (the first distinctive) word of its beginning (רבי הושעי' רבה...) or from its being the most voluminous[1] *Midrash*; hence also *Rabbo* (רבא). The *Midrash* on Canticles (and Ecclesiastes) is now and then also called *Midrash Hazitha* (from the first distinctive word of the beginning חזית). These ten *Midrashim* are, certainly, of various styles and ages; yet none of them is, interpolation excepted, later than the beginning of the 5th century.[2] It is remarkable that, although the *Megilloth* themselves had been early attached to the Pentateuch (since they were long before the 10th century, and still are, read through the synagogal year, even as was and still is the Pentateuch itself), the *Rabboth* had no common *editio princeps*[3]—that on the Pentateuch appearing for the first time in 1512 (Constantinople, folio), and that on the *Megilloth* in 1519 (somewhere in Italy, במדינת איטליאה, also in folio).[4] The latest and best edition is that of Vilna, 1880, folio. A translation in German is now coming out at Leipsic, by Dr A. Wünsche.

(13) *Pirke de-Rabbi Eli'ezer* (also called *Boraitho de-Rabbi Eli'ezer*) is an astronomico-theosophical *Midrash* consisting of fifty-four *Perakim*. It goes through the so-called "eighteen benedictions," the signs of the zodiac, &c., but is unfinished. It belongs, no doubt, to the 5th century. The fact that the name "Fatima" occurs in it is no proof whatever that the book is post-Mohammedan, as that name must have been already known to the idolatrous Arabs. *Ed. prin.*, Constantinople, 1514, and with a Latin translation, Leyden, 1644, both editions being in 4to. There are also now to be found cheap editions (Lemberg, Warsaw).

(14) *Tanhuma* is an exegetical and homiletical *Midrash* on the whole Pentateuch. It is quoted according to the *Parshiyyoth* of the week. Although originally of the end of the 5th or the beginning of the 6th century, it has now two principal additions, which form part of the book:—(1) several of the *Sheelloth* of Rab Ahai Gaon (of the 8th century), and (2) several pieces of the *Yesod* of R. Mosheh Haddarshan, of Narbonne (of the 11th century). On its relation to the "*Yelammedenu*" (often quoted in the 11th century, but supposed to be lost) light will soon be thrown by the before-mentioned Salomon Buber, who is now preparing a critical edition of it. The *ed. princ.* of the *Tanhuma* is Constantinople, 1522, folio; and a very valuable MS. copy of it is in the Cambridge University Library (Add. 1212).

(15) *Bahir* is a small cabbalistic *Midrash* ascribed to the pre-Mishnic teacher, R. Nehunyah b. Hakkanah,—no doubt from its beginning with the words אמר רבי נחוניה בן הקנה.... Nahmanides (*ob. c.* 1268) quotes this book often in his commentary on the Pentateuch, under the names of *Sepher Habbahir*, or of *Midrasho shel Rabbi Nehunyah b. Hakkanah*. Some have pronounced this work a late fabrication, but others, who have thoroughly studied it, justly describe it as "old in substance if not in form." *Ed. princ.*, Amsterdam, 1651, 4to. A cheap edition appeared at Lemberg (1865, 8vo), and a MS. of this work is preserved in the University Library of Cambridge (Dd. 10. 11. 4).

(16) *Yalkut* is the only existing systematic if not exhaustive collection of the *Agadoth* on the whole Bible. Its author drew not only from most of the *Midrashim* named in this article, but also from the *Boraithoth* (see MISHNAH), both *Talmudim*, and the Midrashic works now lost (as the *Abkhir*, *Hasshekhem*, or *Hashkem*, &c.).[5] This fact constitutes one of the principal points of its value. The author was R. Shim'eon, brother (and not son) of R. Helbo, and father of the distinguished grammarian, critic, and divine R. Yoseph Kara. He lived somewhere in the north of France in the 11th century. The *ed. princ.* of the *Yalkut* on Ezra, Nehemiah, and the books of Chronicles came out at Venice, 1517, folio (in the first Rabbinic Bible); that on the Prophets and Hagiographa in 1521, and that on the Pentateuch in 1526–27, both at Salonika, and in folio. An English translation of the whole work has been undertaken by a band of Rabbinic scholars in Cambridge. The first instalment, "The Yalkut on Zechariah," by E. G. King, B.D., Hebrew lecturer of Sidney Sussex College, appeared in 1882. This specimen, besides giving a correct translation, contains many valuable notes.

(17) *Lekah Tob* is a *Midrash* on the Pentateuch and the five *Megilloth*, by R. Tobiyyahu b. Eli'ezer of Greece, who lived during the crusade of 1096. This work draws, certainly, upon the old and well-known *Midrashim*, and as such it would have thoroughly deserved the censure passed upon it by the witty but somewhat irreverent Abraham Ibn 'Ezra (in his preface to his commentary on the Pentateuch). But the *Lekah Tob* has also most valuable explanations both by the collector himself and by his father (R. Eli'ezer), a fact passed over by Ibn 'Ezra in silence. The *Lekah Tob* on Leviticus, Numbers, and Deuteronomy came out for the first time at Venice, in 1546, folio, under the title of *Pesikto Zuttarto* (see leaf 93*b* in the postscript by the editor, הפסיקתא זוטרתא, which explains the somewhat vague title on the title-page פסיקתא זוטרתא או רבתא). In 1753–54 it was republished at Venice, with a Latin translation, by Blasius Ugolinus in his *Thesaurus Antiquitatum Sacrarum* (xv.–xvi.) under the name of *Pesictha*. The *Lekah Tob* on Genesis and Exodus was

[1] The *Rabbah* on Genesis has 100 *Parshiyyoth*, that on Exodus 52, that on Leviticus 37, that on Numbers 23, and that on Deuteronomy 11. These five *Midrashim* are quoted according to their chapters. The *Rabbah* on Canticles accommodates itself to the sacred text, and is quoted accordingly. Ruth has 8 *Parshiyyoth*, and is quoted according to these. Lamentations has 1 chapter consisting of 33 introductions (*Pethihotho Dehakkime*), accommodating itself, for the rest, to the sacred text. Ecclesiastes has 3 *Sedarim*, and Esther has 6 *Parshiyyoth*. At various times various modes of quoting these *Midrashim* are current,—the most common and most expedient, however, being that of quoting them according to the verses of the Bible.

[2] Here might with advantage be mentioned some pieces of literature which are kindred in nature, although some of them are of much earlier date, whilst others are much later, than the ten *Midrashim* just mentioned:—(1) *Agadath Bereshith* on Genesis, in eighty-three chapters,—edited for the first time by R. Menahem de Lonsano in his *Shete Yadoth*, Venice, 1618, 4to; (2) *Midrash Vayyisa'u* on Genesis xxxv. 5, in one chapter,—to be found in Jellinek's *Bet ha-Midrasch*, Leipsic, 1855, 8vo; (3) amplifications of chapter lxx. of our *Midrash Rabbah*, on Genesis xxviii. 22, by the incorporation of the whole Apocryphon *Tobit* in Aramaic, &c. (see *The Book of Tobit*, &c., Oxford, 1878, 8vo); (4) *Midrash Vayyosha'* on Exodus xiv. 30, xv. 1–18,—printed at Constantinople, 1519, 4to; a MS. of this *Midrash* is preserved in the University Library, Cambridge (Add. 854); (5) *Midrash 'Asereth Haddibberoth* on Exodus xx.,—printed in Jellinek's *Bet ha-Midrasch*, Leipsic, 1853, 8vo; (6) *Midrash Petirath Aharon* on Numbers xx. 23–29; (7) *Midrash Petirath Mosheh* on Deuteronomy xxxiv.; (8) *Midrash Abbo Gorion* on Esther; the last three are to be found in the before-mentioned *Bet ha-Midrasch*; (9) *Midrash Shemuel*, also called, from its beginning, *'Eth la'asoth Ladonai*, Constantinople, 1517, folio; (10) *Midrash Yonah*, Prague, 1595, 4to; (11) *Midrash Tillim* (*Tehillim*), 1512; (12) *Midrash Mishele*, 1517; the last two are printed at Constantinople, and in folio; (13) *Sepher Hayyashar* (in which a good many old traditions are preserved, although it is, of course, not the one mentioned in various books of the Bible), Venice, 1625, 4to; (14) *Dibere Hayyamim shel Mosheh*, Constantinople, 1516, 4to; a fragment of this is to be found in MS. Add. 532. 4 in the University Library of Cambridge; (15) *Yosephon* (or *Josippon*), various works of Flavius Josephus worked up rather freely, Mantua, 1480, folio,—translated into Latin (German and Spanish) several times; (16) *Zerubbabel*, Constantinople, 1519, 8vo; (17) *Elleh Ezkerah* on the "Ten Martyrs." For several other smaller *Midrashim* see Jellinek's *Bet ha-Midrasch*, i. and ii., 1853, iii., 1855, iv., 1857, all at Leipsic; v., 1873, and vi., 1877, both at Vienna; and comp. also Horowitz, *Sammlung Kleiner Midraschim*, i., ii., Frankfort, 1881–82. The *Midrashim* on Isaiah and on Job seem now irretrievably lost.

[3] As if to compensate for this drawback, the well-known Cornelio Adelkind brought out at Venice, in 1545, two editions of the *Rabboth* on the Pentateuch and *Megilloth*, the one at Bombergi's house and the other at Giustiniani's. These two editions differ in nothing but in the title-pages, &c., and the vignettes of the various books. The former edition is in possession of Dr W. Aldis Wright, and the latter in that of Dr C. Taylor. The fact of these editions having appeared simultaneously is, apparently, unknown to the bibliographers.

[4] It is noteworthy that in this edition *Ahashverosh*, *i.e.*, Esther, stands between Lamentations and Ecclesiastes, with which latter the *Midrash* on the *Megilloth* ends.

[5] We may mention here the *ed. princ.* of three cabbalistic-Midrashic collections which go under the name of *Yalkut*:—(1) *Yalkut Hadash*, Lublin, 1648, 4to; (2) *Yalkut Reubeni Hakkatan*, Prague, 1660, 4to; and (3) *Yalkut Reubeni Haggadol*. Wilhermsdorf, 1681, folio.

published, with a critical commentary, at Vilna, by Salomon Buber (1880, 8vo), where also simultaneously a third edition of this *Midrash* on the last three books of Moses, with a short commentary on it, came out by Aharon Mosheh Padova, of Carlin. The *Leḳah Tob* on the five *Megilloth* is as yet unpublished; there exist, however, several good MSS. of it, both in public and private libraries, the finest copy in every respect being that preserved in the University Library, Cambridge (Add. 378. 1).

(18) *Menorath Hammaor* is a scientific, though incomplete, collection of the principal *Agadoth* of the *Talmudim* and *Midrashim*, by R. Yizḥaḳ Abohab the elder (flourished 13th century). The editions, with and without translations, are very numerous,—the *ed. princ.* being Constantinople, 1514, folio. There are translations in Spanish, Judæo-German, and German, but not in English.

We append two specimens of *Midrashim*,—the first from *Pesiḳotho*, leaf 127*b*, and the second from *Midrash Shemoth Rabbah*, cap. ii.

First Specimen.—The Holy One (blessed be He!) said to the Prophets,[1] Go ye and comfort ye Jerusalem!

Then went Hosea to comfort her and said, The Holy One (blessed be He!) sent me to thee to comfort thee. She said, What hast thou in thine hand to comfort me? The Prophet said (xiv. 6 [5]), "I will be as the dew unto Israel!" But Jerusalem said to him, Only yesterday thou toldest me (ix. 16), "Ephraim is smitten, their root is dried up, they shall bear no fruit: yea, though they bring forth, yet will I slay even the beloved fruit of their womb!" and now thou speakest to me thus. Which shall we believe, the first or the second prophecy?

Then went Joel to comfort her and said, The Holy One (blessed be He!) sent me to thee to comfort thee. She said to him, What hast thou in thine hand to comfort me? The Prophet said (iv. 18), "And it shall come to pass in that day that the mountains shall drop down new wine, and the hills shall flow with milk, &c.!" But Jerusalem said to him, Only yesterday thou toldest me (i. 5), "Awake, ye drunkards, and weep; and howl, all ye drinkers of wine, because of the new wine; for it is cut off from your mouth!" and now thou speakest to me thus. Which shall we believe, the first or the second prophecy?

Then went Amos to comfort her and said, The Holy One (blessed be He!) sent me to thee to comfort thee. She said to him, What hast thou in thine hand to comfort me? The Prophet said (ix. 11), "In that day will I raise up the tabernacle of David that is fallen!" But Jerusalem said to him, Only yesterday thou toldest me (v. 2), "The Virgin of Israel is fallen; she shall no more rise!" and now thou speakest to me thus. Which shall we believe, the first or the second prophecy?

Then went Micah[2] to comfort her and said, The Holy One (blessed be He!) sent me to thee to comfort thee. She said to him, What hast thou in thine hand to comfort me? The Prophet said (vii. 18), "Who is a God like unto Thee, that pardoneth iniquity and passeth by the transgression of the remnant of His heritage?" But Jerusalem said to him, Only yesterday thou toldest me (i. 5), "For the transgression of Jacob is all this, and for the sins of the house of Israel, &c.!" and now thou speakest to me thus Which shall we believe, the first or the second prophecy?

Then went Nahum to comfort her and said, The Holy One (blessed be He!) sent me to thee to comfort thee. She said to him, What hast thou in thine hand to comfort me? The Prophet said (ii. 1 [i. 15]), "For the wicked shall no more pass through thee!" But Jerusalem said to him, Only yesterday thou toldest me (i. 11), "There is one come out of thee that imagineth evil against the Lord, a wicked counsellor!" and now thou speakest to me thus. Which shall we believe, the first or the second prophecy?

Then went Habakkuk to comfort her and said, The Holy One (blessed be He!) sent me to thee to comfort thee. She said to him, What hast thou in thine hand to comfort me? The Prophet said (iii. 13), "Thou wentest forth for the salvation of Thy people, even for the salvation with Thine Anointed One!" But Jerusalem said to him, Only yesterday thou toldest me (i. 2), "O Lord, how long shall I cry and Thou wilt not hear, even cry out unto Thee of violence and Thou wilt not save!" and now thou speakest to me thus. Which shall we believe, the first or the second prophecy?

Then went Zephaniah to comfort her and said, The Holy One (blessed be He!) sent me to thee to comfort thee. She said to him, What hast thou in thine hand to comfort me? The Prophet said (i. 12), "And it shall come to pass at that time that I shall search Jerusalem with lights!" But Jerusalem said to him, Only yesterday thou toldest me (i. 15), "A day of darkness and gloominess!" and now thou speakest to me thus. Which shall we believe, the first or the second prophecy?

Then went Haggai to comfort her and said, The Holy One (blessed be He!) sent me to thee to comfort thee. She said to him, What hast thou in thine hand to comfort me? The Prophet said (ii. 19), "Is the seed yet in the barn! Yea, as yet the vine and the fig tree and the pomegranate and the olive tree hath not brought forth: from this day will I bless you!" But Jerusalem said to him, Only yesterday thou toldest me (i. 6), "Ye have sown much and bring in little, &c.!" and now thou speakest to me thus. Which shall we believe, the first or the second prophecy.

Then went Zechariah to comfort her and said, The Holy One (blessed be He!) sent me to thee to comfort thee. She said to him, What hast thou in thine hand to comfort me? The Prophet said (i. 15), "And I am very sore displeased with the heathen that are at ease: for I was but a little displeased and they helped forward the affliction!" But Jerusalem said to him, Only yesterday thou toldest me (i. 2), "The Lord hath been sore displeased with your fathers!" and now thou speakest to me thus. Which shall we believe, the first or the last prophecy?

Then went Malachi to comfort her and said, The Holy One (blessed be He!) sent me to thee to comfort thee. She said to him, What hast thou in thine hand to comfort me? The Prophet said (iii. 12), "And all nations shall call you blessed: for ye shall be a delightsome land!" But Jerusalem said to him, Only yesterday thou toldest me (i. 10), "I have no delight in you!" and now thou speakest to me thus. Which shall we believe, the first or the last prophecy?

Then went all the Prophets to the Holy One (blessed be He!) saying to Him, Lord of the Universe, Jerusalem will not accept consolation at our hands. Then the Holy One (blessed be He!) said to them, "I and you will together go to comfort her; and this is why it says (Isaiah xl. 1), Comfort ye, comfort ye my people, comfort her with me.[3] Comfort her, ye celestial ones! comfort her, ye terrestrial ones! Comfort her, ye living ones! comfort her, ye dead ones! Comfort her in this world! comfort her in the world to come!

[1] Comp. *Pesiḳto Rabbathi*, ed. Friedmann, leaf 138*b*.

[2] See *Pesiḳto Rabbathi* (ed. Friedmann, leaf 138*b*), where it says (before the paragraph on *Nahum*), "'Obadyah prophesied for Edom, and Yonah for Nineveh." This, it is true, is a mere gloss; but it is the true reason why these two prophets are left out.

[3] There is a play here upon the meaning of the Hebrew עמי, which may be read either '*Ammi* ("my people") or '*Immi* ("with me").

Second Specimen.—And whom does He try? The righteous one; for it says (Ps. xi. 5), "The Lord trieth the righteous." And by what does He try him? By the feeding of sheep. David He tried by sheep and found him a good shepherd, for it says (Ps. lxxviii. 70), "And He took him from the 'restraints' of sheep." What is the meaning of '*Mimmikhleoth?*' The root is the same as that of '*vayyikkale* [*haggeshem*] (Gen. viii. 2), "And the rain was restrained." David restrained the big sheep in favour of the small ones. He brought out first the young ones, so that they should feed on the tender herbs; then he brought out the old ones that they should feed on the less tender herbs; and, finally, he brought out the strong sheep that they should feed on the coarser herbs. Upon this the Holy One (blessed be He!) said, He who understandeth to feed sheep according to their strength, let him come and feed My people! And this it is what is written (Ps. lxxviii. 71), "*From following the ewes great with young He brought him to feed Jacob His people!*" And the same was the case as regards Moses, whom the Holy One (blessed be He!) tried by sheep. Our rabbis say, When Moses our teacher (peace be upon him!) was feeding the sheep of Jethro in the wilderness, a kid ran away from him, and Moses ran after it till they came to a mountain-hollow. When it had reached the mountain-hollow there was a pool of water, and the kid stood still in order to drink. When Moses reached the kid he said to it, I did not know that thou didst run away from me because thou wast thirsty and faint. Thereupon he put it on his shoulders and walked back with it to the flock.[4] Then said the Holy One (blessed be He!), Thou art compassionate in the feeding of sheep belonging to mere flesh and blood (man); as thou livest, thou shalt feed My flock, even Israel! Behold, this it is that is written (Exod. iii. 1), "And Moses was feeding the flock, &c." (S. M. S.-S.)

MIEDZYRZECZ PODLASKI (Russian, *Mejiryechie*), a district town of Russian Poland, in the government of Siedlce, 16 miles to the east of the government capital, on the railway between Warsaw and Brest-Litovskiy. It is first mentioned in the year 1390 as a feudal dominion of King Yaghello. After frequently changing hands it became the property of the Czartoryski, and afterwards of the Potocki family, whose palace is still to be seen in the town. Its 10,000 inhabitants—half of whom are Greek nonconformists, and half Jews and Poles—carry on some trade in bristles, and pursue minor industries.

MIERIS, the name of a family of artists who practised painting at Leyden for three generations in the 17th and 18th centuries.

I. Frans van Mieris, the elder, son of Jan van Mieris, a goldsmith and diamond setter, was born, according to Houbraken, at Leyden on the 16th of April 1635, and died there on the 12th of March 1681. His father wished to train him to his own business, but Frans preferred drawing to chasing, and took service with Abraham Torenvliet, a glazier who kept a school of design. As often happens, the youth's style was influenced by his earliest surroundings. In his father's shop he became familiar with the ways and dress of people of distinction. His eye was fascinated in turn by the sheen of jewellery and stained glass; and, though he soon gave up the teaching of Torenvliet for that of Gerard Dow and Abraham van den Tempel, he acquired a manner which had more of the finish of the exquisites of the Dutch school than of the breadth of the disciples of Rembrandt. It should be borne in mind that he seldom chose panels of which the size exceeded 12 to 15 inches, and whenever his name is attached to a picture above that size we may surely assign it to his son Willem or to some other imitator. Unlike Gerard Dow when he first left Rembrandt, or Jan Steen when he started on an independent career, he never ventured to design figures as large as life. Characteristic of his art in its minute proportions is a shiny brightness and metallic polish. The subjects which he treated best are those in which he illustrated the habits or actions of the wealthier classes; but he sometimes succeeded in homely incidents and in portrait, and not unfrequently he ventured on allegory. He repeatedly painted the satin skirt which Terburg brought into fashion, and he often rivalled Terburg in the faithful rendering of rich and highly-coloured woven tissues. But he remained below Terburg and Metzu, because he had not their delicate perception of harmony or their charming mellowness of touch and tint, and he fell behind Gerard Dow, because he was hard and had not his feeling for effect by concentrated light and shade. In the form of his composition, which sometimes represents the framework of a window enlivened with

[4] Who, on reading this, does not think of such passages in the New Testament as Matt. xviii. 12, xxv. 21, and John x. 14?

greenery, and adorned with bas-reliefs within which figures are seen to the waist, his model is certainly Gerard Dow. It has been said that he possessed some of the humour of Jan Steen, who was his friend, but the only approach to humour in any of his works is the quaint attitude and look of a tinker in a picture at Dresden, who glances knowingly at a worn copper kettle which a maid asks him to mend.

It is a question whether Houbraken has truly recorded this master's birthday. One of his best-known pieces, a party of ladies and gentlemen at an oyster luncheon in the hermitage at St Petersburg, bears the date of 1650. Celebrated alike for composition and finish, it would prove that Mieris had reached his prime at the age of fifteen. Another beautiful example, the Doctor Feeling a Lady's Pulse in the gallery of Vienna, is dated 1656; and Waagen, in one of his critical essays, justly observes that it is a remarkable production for a youth of twenty-one. In 1657 Mieris was married at Leyden in the presence of Jan Potheuck, a painter, and this is the earliest written record of his existence on which we can implicitly rely. Of the numerous panels known to the writer of these lines, twenty-nine at least are dated,—the latest being an allegory, long in the Ruhl collection at Cologne, illustrating the kindred vices of drinking, smoking, and dicing, in the year 1680.

Mieris had numerous and distinguished patrons. He received valuable commissions from Archduke Leopold, the elector-palatine, and Cosmo III., grand-duke of Tuscany. His practice was large and lucrative, but never engendered in him either carelessness or neglect. If there be a difference between the painter's earlier and later work, it is that the former was clearer and more delicate in flesh, whilst the latter was often darker and more livid in the shadows. When he died his clients naturally went over to his son Willem, who in turn bequeathed his painting-room to his son Frans. But neither Willem nor Frans the younger equalled Frans the elder.

II. Willem van Mieris (1662–1747), son of Frans. His works are extremely numerous, being partly imitations of the paternal subjects, or mythological episodes, which Frans habitually avoided. In no case did he come near the excellence of his sire.

III. Frans van Mieris the younger (1689–1763) also lived on the traditions of his grandfather's painting-room.

The pictures of all the generations of the Mieris family were successfully imitated by A. D. Snaphaan, who lived at Leipsic and was patronized by the court of Anhalt-Dessau. To those who would study his deceptive form of art a visit to the collection of Wörlitz near Dessau may afford instruction.

MIGNARD, Pierre (1610–1695), called—to distinguish him from his brother Nicholas—Le Romain, was the chief French portrait-painter of the 17th century. He was born at Troyes in 1610, and came of a family of painters. In 1630 he left the studio of Simon Vouet for Italy, where he spent twenty-two years, and made a reputation which brought him a summons to Paris. Successful with his portrait of the king, and in favour with the court, Mignard pitted himself against Le Brun, declined to enter the Academy of which he was the head, and made himself the centre of opposition to its authority. The history of this struggle is most important, because it was identical, as long as it lasted, with that between the old guilds of France and the new body which Colbert, for political reasons, was determined to support. Shut out, in spite of the deserved success of his decorations of the cupola of Val de Grace (1664), from any great share in those public works the control of which was the attribute of the new Academy, Mignard was chiefly active in portraiture. Turenne, Bossuet, Maintenon (Louvre), La Vallière, Sévigné, Montespan, Descartes (Castle Howard), all the beauties and celebrities of his day, sat to him. His readiness and skill, his happy instinct for grace of arrangement, atoned for want of originality and real power. With the death of Le Brun (1690) the situation changed; Mignard deserted his allies, and succeeded to all the posts held by his opponent. These late honours he did not long enjoy; in 1695 he died whilst about to commence work on the cupola of the Invalides. His best compositions have been engraved by Audran, Edelinck, Masson, Poilly, and others.

MIGNONETTE, or Mignonnette (*i.e.*, "little darling"), the name given to a popular garden flower, the *Reseda odorata* of botanists, a "fragrant weed," as Cowper calls it, highly esteemed for its delicate but delicious perfume. The mignonette is generally regarded as being of annual duration, and is a plant of diffuse decumbent twiggy habit, scarcely reaching a foot in height, clothed with bluntish lanceolate entire or three-lobed leaves, and bearing longish spikes—technically racemes—of rather insignificant flowers at the ends of the numerous branches and branchlets. The plant thus naturally assumes the form of a low dense mass of soft green foliage studded over freely with the racemes of flowers, the latter unobtrusive and likely to be overlooked until their diffused fragrance compels attention. The native country of the original or typical mignonette has sometimes been considered doubtful, but according to the best and latest authorities it has been gathered wild on the North African coast near Algiers, in Egypt, and in Syria. As to its introduction, a MS. note in the library of Sir Joseph Banks records that it was sent to England from Paris in 1742; and ten years later it appears to have been sent from Leyden to Philip Miller at Chelsea. Though originally a slender and rather straggling plant, there are now some improved garden varieties in which the growth is more compact and vigorous, and the inflorescence bolder, though the odour is perhaps less penetrating. The small six-petalled flowers are somewhat curious in structure: the two upper petals are larger, concave, and furnished at the back with a tuft of club-shaped filaments, which gives them the appearance of being deeply incised, while the two lowest petals are much smaller and undivided; the most conspicuous part consists of the anthers, which are numerous and of a brownish red, giving the tone of colour to the inflorescence. In a new variety named Golden Queen the anthers have a decided tint of orange-yellow, which imparts a brighter golden hue to the plants when in blossom. A handsome proliferous or double-flowered variety has also been obtained, which is likely to be a very useful decorative plant, though only to be propagated by cuttings; the double white flowers grow in large massive panicles (proliferous racemes), and are equally fragrant with those of the ordinary forms.

What is called tree mignonette in gardens is due to the skill of the cultivator. Though practically a British annual, as already noted, since it flowers abundantly the first season, and is utterly destroyed by the autumnal frosts, and though recorded as being annual in its native habitat by Desfontaines in the *Flora Atlantica*, the mignonette, like many other plants treated in England as annuals, will continue to grow on if kept in a suitable temperature. Moreover, the life of certain plants of this semiannual character may be prolonged into a second season if their flowering and seeding are persistently prevented. In applying these facts to the production of tree mignonette, the gardener grows on the young plants under glass, and prevents their flowering by nipping off the blooming tips of the shoots, so that they continue their vegetative growth into the second season. The young plants are at first supported in an erect position, the laterals being removed so as to secure clean upright stems, and then at the height of one or two feet or more, as may be desired, a head of branches is encouraged to develop itself. In this way very large plants can be produced.

For ordinary purposes, however, other plans are adopted. In the open borders of the flower garden mignonette is usually sown in spring, and in great part takes care of itself; but, being a favourite either for window or balcony culture, and on account of its fragrance a welcome inmate of town conservatories, it is also very extensively

grown as a pot plant, and for market purposes with this object it is sown in pots in the autumn, and thinned out to give the plants requisite space, since it does not transplant well, and it is thereafter specially grown in pits protected from frosts, and marketed when just arriving at the blooming stage. In this way hundreds of thousands, probably, of pots of blooming mignonette are raised and disposed of year by year.

In classifying the odours given off by plants Rimmel ranks the mignonette in the class of which he makes the violet the type; and Fée adopts the same view, referring it to his class of "iosmoids" along with the violet and wallflower.

The name is sometimes, but it would appear less correctly, written mignionette. The genus *Reseda* contains some other interesting and useful species,—among them the *Reseda Luteola*, which is commonly called dyer's-weed and weld, and yields a valuable yellow dye.

MIGUEL, MARIA EVARIST (1802–1866), usually known as DON MIGUEL, whose name is chiefly associated with his pretensions to the throne of Portugal, was the third son of King John VI. of Portugal, and of Carlotta Joachima, one of the Spanish Bourbons; he was born at Lisbon on October 26, 1802. In 1807 he accompanied his parents in their flight to Brazil, where he was permitted to grow up a spoiled child and a worthless youth; in 1821, on his return to Europe, it is said that he had not yet learned to read. In 1822 his father swore fidelity to the new Portuguese constitution which had been proclaimed in his absence; and this led Carlotta Joachima, who was an absolutist of the extremest Bourbon type, and otherwise hated her husband, to resolve to seek his dethronement in favour of Miguel her favourite son. The insurrections which ensued (see PORTUGAL) resulted in her relegation to the castle of Queluz and the exile of Miguel (1824), who spent a short time in Paris and afterwards lived in Vienna, where he came under the teaching of Metternich. On the sudden death of John VI. in May 1826, Pedro of Brazil, his eldest son, renounced the crown in favour of his daughter Maria da Gloria, on the understanding that she should become the wife of Miguel. The last-named accordingly swore allegiance to Pedro, to Maria, and to the constitution which Pedro had introduced, and on this footing was appointed regent in July 1827. He arrived in Lisbon in February 1828, and, regardless of his promises, dissolved the new Cortes in March; having called together the old Cortes, with the support of the reactionary party of which his mother was the ruling spirit, he got himself proclaimed sole legitimate king of Portugal in July. The power which he now enjoyed he wielded in the most tyrannical manner for the repression of all liberalism, and his private life was characterized by the wildest excesses. The public opinion of Europe became more and more actively hostile to his reign, and after the occupation of Oporto by Don Pedro in 1832, the destruction of Miguel's fleet by Captain (afterwards Sir Charles) Napier off Cape St Vincent in 1833, and the victory of Saldanha at Santarem in 1834, Queen Christina of Spain recognized the legitimate sovereignty of Maria, and in this was followed by France and England. Don Miguel capitulated at Evora on May 29, 1834, renouncing all pretensions to the Portuguese throne, and solemnly promising never thenceforward to meddle in Peninsular affairs. He lived for some time at Rome, where he enjoyed papal recognition, but afterwards retired to Bronnbach, in Baden, where he died on November 14, 1866.

MIGULINSKAYA, a Cossack village (*stanitsa*) of Russia, in the government of the Don Cossacks, and in the district of Ust-Medvyeditsa, 79 miles to the west of that town, on the left bank of the Don. It is one of the largest and wealthiest *stanitsas* of the government, and has 20,600 inhabitants, who are engaged in agriculture and stock-breeding, and in the export of agricultural produce.

MIKHAILOVSKAYA, a Cossack village (*stanitsa*) of Russia, in the government of the Don Cossacks, and in the district of Khopersk, 14 miles to the north-west of Uryupino, on the low left bank of the Khoper, which is inundated when the river is full. It has an important fair, where Tartars from Astrakhan exchange furs and cottons for manufactured and grocery wares imported from central Russia; the inhabitants of the district also sell corn, cattle, and plain woollen stuffs. Population, 18,000.

MILAN (the Latin *Mediolanum*, Italian *Milano*, and German *Mailand*), a city of Italy, situated near the middle of the Lombard plain, on the small river Olona, in 45° 27′ 35″ N. lat. and 9° 5′ 45″ E. long. It is 390 feet above the sea-level, and lies 25 miles south of the Alps at Como, 30 miles north of the Apennines, 20 miles east of the Ticino, and 15 miles west of the Adda.

The plain around Milan is extremely fertile, owing at once to the richness of the alluvial soil deposited by the Po, Ticino, Olona, and Adda, and to the excellent system of irrigation. Seen from the top of the cathedral, the plain presents the appearance of a vast garden divided into square plots by rows of mulberry or poplar trees. To the east this plain stretches in an unbroken level, as far as the eye can follow it, towards Venice and the Adriatic; on the southern side the line of the Apennines from Bologna to Genoa closes the view; to the west rise the Maritime, Cottian, and Graian Alps, with Monte Viso as their central point; while northward are the Pennine, Helvetic, and Rhætian Alps, of which Monte Rosa, the Saasgrat, and Monte Leone are the most conspicuous features. In the plain itself lie many small villages; and here and there a larger town like Monza or Saronno, or a great building as the Certosa of Pavia, makes a white point upon the greenery.

The commune of Milan consists since 1873 of the city within the walls (area 1513 acres) and the so-called Corpi Santi[1] without the walls (area 15,415 acres). The population of the whole area increased from 134,528 in 1800 to 242,457 in 1861, 261,985 in 1871, and 321,839 in 1881,—the city within the walls contributing 110,884 in 1801, 196,109 in 1861, 199,009 in 1871, and 214,004 in 1881. The climate is very variable; there is a difference of 41° Fahr. between the extreme summer heat and winter cold. The average number of wet days is 72, and of snowy days 10 per annum.

Milan is built in a circle, the cathedral being the central point. The city is surrounded by a wall 7 miles in circumference, and immediately outside the wall a fine broad thoroughfare makes the circuit of the city. The streets inside are for the most part narrow and crooked; the main streets are the Corso Vittorio Emanuele, the Strada S. Margherita, the Via Manzoni, the Corso Porta Ticinese, and the Corso Porta Romana. There are few piazzas of any size; the largest is the Piazza del Duomo, which has recently been extended, and the houses around it modernized. To the west of the city is the open space of the Foro Bonaparte and the Piazza d'Armi, with the square keep of the Visconti castle, flanked by two granite towers, between them. The castle was partly destroyed in 1447 by the Ambrosian republic, rebuilt by Francesco Sforza, enlarged by the Spanish governors, and taken by Napoleon in 1800, when the outer fortifications were razed to the ground, and the walls left as they now are. North of the Piazza d'Armi is the modern cemetery, with a special building and apparatus for cremation, erected in 1876.

Among the buildings of Milan the most important is the cathedral, begun under Gian Galeazzo Visconti, in 1386. It is built of brick cased in marble from the quarries which Visconti gave in perpetuity to the cathedral chapter. The

[1] The name Corpi Santi (of doubtful origin) is also applied to the extra-mural portions of Cremona and Pavia.

but it is not so rich in MSS. as the celebrated Ambrosian library, for which see LIBRARIES, vol. xiv. p. 531.

Agriculture.—The district of Milan is renowned for its excellent agriculture. It may be divided into two regions, where different systems of farming are pursued and different crops produced. The first region lies on the lower slopes of the Alps, where they sink into the plain. This is called the dry Milanese, for it is watered by torrents only, which have worn themselves too deep a bed to allow of irrigation, and the peasants are obliged to collect the rain-water in large mud-lined tanks called "poppe." The soil is for the most part thin and light, and is frequently washed down the incline into the plain; in some parts it is only kept in its place by stone walls reared at great cost. The farms are smaller here than in the lower plain, and are let on a system which is a compromise between the mezzadria, which once obtained in the district, and regular leases. The tenant pays a money rent for the house; and for the land he either pays in kind or in a money equivalent, supplemented by labour given to the landlord. In cases where vines or fruit trees are grown, the landlord supplies and maintains them till they come into fruit. The landlord carries out all improvements, and the tenant holds the farm at his pleasure. The rotation of cropping is for three years. The value of these farms varies greatly, ranging from 7 to 14 lire the pertica (1000 square yards). The district produces maize and wheat in abundance, a little flax and millet, apples, and wine. The second agricultural district is that which lies in the plain; it is called the wet Milanese, from the elaborate system of irrigation which makes the meadows yield a constant succession of crops. The plain is traversed by innumerable canals at various levels, crossing one another on bridges, or by siphons, so that the peasant can flood his fields at any moment. The system is as old as the 12th century; it was improved by Leonardo da Vinci, and is now the most perfect network of irrigation in Europe. The farms vary in extent from 1500 to 4500 pertiche. They are let upon leases for nine, twelve, or fifteen years, at rents ranging from 8·50 to 12·50 lire the pertica, while those near a city may bring from 15 to 20 lire. The rotation of cropping is five-yearly. The meadows yield four crops of grass in the year; the first three—the maggengo, the agostino, and the terzuolo—are cut, the fourth is grazed off. Where the ground is perfectly flat and water can stagnate, rice is grown; this crop is continued for four years in succession, then the land is rested with cereals and grass. The other crops are maize and wheat. But the chief occupation is the supply of dairy produce. The cows are bought in the Swiss cantons of Uri, Zug, Lucerne, and Schwyz, the last furnishing the best milkers. The cheese called Parmesan comes from the Milanese; and the rich cheese, made of unskimmed milk, known as Stracchino, is made principally at the village of Gorgonzola, 12 miles east of Milan.

Industries.—The industries of this district have increased very rapidly since the union of Italy, and the city is now the chief commercial centre in North Italy. The principal industry of Milan and the Milanese is the production and manufacture of silk. For feeding the worms mulberry trees are largely cultivated on the plain; and the district counts upwards of 200 factories, where the silk thread is unwound from the cocoons, yielding 4,000,000 ℔ of raw silk in the year. Some of this is exported to France for manufacture, but the Milanese can now almost rival their neighbours in the production of silk stuffs, velvets, and brocades. Cotton is manufactured at Saronno and Legnano, fustian at Busto, linen at Cassano, combs at Burlando, and porcelain and carriages of very excellent workmanship in Milan itself.

History.—Bellovesus, king of the Celts, who crossed the Alps when Tarquinius Priscus was king in Rome, is the traditional founder of Milan. The city became the capital of the Insubrian Gauls, and was taken by the Romans in 222 B.C. As a Roman municipium it continued to increase in magnificence and importance; and under Constantine it was the seat of the imperial vicar of the West. Under Theodosius, in the 4th century, Milan, to judge from Ausonius's description (*Ordo Nob. Urbium*, v.), must have been rich in temples and public buildings. Theodosius died at Milan after doing penance, at the bidding of St Ambrose, for his slaughter of the people of Thessalonica. Ambrose is still venerated in Milan as the founder of the Milanese church and the compiler of the Ambrosian rite, which is still in use throughout the diocese. After his death the period of invasions begins; and Milan felt the power of the Huns under Attila (452), of the Heruli under Odoacer (476), and of the Goths under Theodoric (493). When Belisarius was sent by Justinian to recover Italy, Datius, the archbishop of Milan, joined him, and the Goths were expelled from the city. But Uraia, nephew of Vitigis the Gothic king, subsequently assaulted and retook the town, after a brave resistance. Uraia destroyed the whole of Milan in 539; and hence it is that this city, once so important a centre of Roman civilization, possesses so few remains of antiquity. Narses, in his campaigns against the Goths, had invited other barbarians, the Lombards, to his aid. They came in a body under Alboin, their king, in 568, and were soon masters of North Italy, and entered Milan the year following. Alboin established his capital at Pavia, and Milan remained the centre of Italian opposition to the foreign conquest.

The Lombards were Arians, and the archbishops of Milan from the days of Ambrose had been always orthodox. Though the struggle was unequal, their attitude of resolute opposition to the Lombards gained for them great weight among the people, who felt that their archbishop was a power around whom they might gather for the defence of their liberty and religion. All the innate hatred of the foreigner went to strengthen the hands of the archbishops, who slowly acquired, in addition to their spiritual authority, powers military, executive, and judicial. These powers they came to administer through their delegates, called viscounts. When the Lombard kingdom fell before the Franks under Charles the Great in 774, the archbishops of Milan were still further strengthened by the close alliance between Charles and the church, which gave a sort of confirmation to their temporal authority, and also by Charles's policy of breaking up the great Lombard fiefs and dukedoms, for which he substituted the smaller counties. Under the confused government of Charles's immediate successors the archbishop was the only real power in Milan. But there were two classes of difficulties in the situation, ecclesiastical and political; and their presence had a marked effect on the development of the people and the growth of the commune, which was the next stage in the history of Milan. On the one hand the archbishop was obliged to contend against heretics or against fanatical reformers who found a following among the people; and on the other, since the archbishop was the real power in the city, the emperor, the nobles, and the people each desired that he should be of their party; and to whichever party he did belong he was certain to find himself violently opposed by the other two. From these causes it sometimes happened that there were two archbishops, and therefore no central control, or no archbishop at all, or else an archbishop in exile. The chief result of these difficulties was that a spirit of independence and a capacity of judging and acting for themselves was developed in the people of Milan. The terror of the Hunnish invasion, in 899, further assisted the people in their progress towards freedom, for it compelled them to take arms and to fortify their city, rendering Milan more than ever independent of the feudal lords who lived in their castles in the country. The tyranny of these nobles drove the peasantry and smaller vassals to seek the protection for life and property, the equality of taxation and of justice, which could be found only inside the walled city and under the rule of the archbishop. Thus Milan grew populous, and learned to govern itself. Its inhabitants became for the first time Milanese, attached to the standard of St Ambrose,—no longer subjects of a foreign conqueror, but a distinct people, with a municipal life and prospects of their own. For the further growth of the commune, the action of the great archbishop Heribert, the establishment of the carroccio, the development of Milanese supremacy in Lombardy, the destruction of Lodi, Como, Pavia, and other neighbouring cities, the exhibition of free spirit and power in the Lombard league, and the battle of Legnano, see the article ITALY. See also LOMBARDS.

After the battle of Legnano, in 1174, although the Lombard cities failed to reap the fruit of their united action, and fell to mutual jealousy once more, Milan internally began to grow in material prosperity. After the peace of Constance (1183) the city walls were extended; the arts flourished, each in its own quarter, under a syndic who watched the interests of the trade. The manufacture of armour was the most important industry. During the struggles with the emperor Barbarossa, when freedom seemed on the point of being destroyed, many Milanese vowed themselves, their goods, and their families to the Virgin should their city come safely out of her troubles. Hence arose the powerful fraternity of the "Umiliati," who established their headquarters at the Brera, and began to develop the wool trade, and subsequently gave the first impetus to the production of silk. From this period also date the irrigation works which render the Lombard plain a fertile garden. The government of the city consisted of (A) a parlamento or consiglio grande, including all who possessed bread and wine of their own,—a council soon found to be unmanageable owing to its size, and reduced first to 2000, then to 1500, and finally to 800 members; (B) a credenza or committee of twelve members, elected in the grand council, for the despatch of urgent or secret business; (C) the consuls, the executive, elected for one year, and compelled to report to the great council at the term of their office. The way in which the burghers used their liberty and powers, secured by the peace of Constance, in attacking the feudal nobility; how they compelled the nobles to come into the city and to abandon their castles for a certain portion of the year; how the war between the two classes was continued inside the city, resulting in the establishment of the podestà; and the nature and limits of this office,—all this has been explained in the article ITALY.

This bitter and well-balanced rivalry between the nobles and the people, and the endless danger to which it exposed the city owing to the fact that the nobles were always ready to claim the protec-

tion of their feudal chief, the emperor, brought to the front two noble families as protagonists of the contending factions,—the Torriani of Valsassina, and the Visconti, who derived their name from the office they had held under the archbishops. After the battle of Cortenova, in 1237, where Frederick II. defeated the Guelf army of the Milanese and captured their carroccio, Pagano della Torre rallied and saved the remnants of the Milanese. This act recommended him to popular favour, and he was called to the government of the city,—but only for the distinct purpose of establishing the "catasta," a property tax which should fall with equal incidence on every citizen. This was a democratic measure which marked the party to which the Torriani belonged and rendered them hateful to the nobility. Pagano died in 1241. His nephew Martino followed as podestà in 1256, and in 1259 as signore of Milan,—the first time such a title was heard in Italy. The nobles, who had gathered round the Visconti, and who threatened to bring Ezzelino da Romano, the Ghibelline tyrant of Padua, into the city, were defeated by Martino, and nine hundred of their number were captured. Martino was followed by two other Torriani, Filippo his brother (1263–65) and Napoleone his cousin (1265–77), as lords of Milan. Napoleone obtained the title of imperial vicar from Rudolph of Hapsburg. But the nobles under the Visconti had been steadily gathering strength, and Napoleone was defeated at Desio in 1277. He ended his life in a wooden cage at Castel Baradello above Como.

Otho Visconti, archbishop of Milan (1262), the victor of Desio, became lord of Milan, and founded the house of Visconti, who ruled the city—except from 1302 to 1310—till 1447, giving twelve lords to Milan. Otho (1277–95), Matteo (1310–22), Galeazzo (1322–28), Azzo (1328–39), Lucchino (1339–49), and Giovanni (1349–54) followed in succession. Giovanni left the lordship to three nephews—Matteo, Galeazzo, and Bernabò. Matteo was killed (1355) by his brothers, who divided the Milanese, Bernabò reigning in Milan (1354–85) and Galeazzo in Pavia (1354–78). Galeazzo left a son, Gian Galeazzo, who became sole lord of Milan by seizing and imprisoning his uncle Bernabò. For an account of this most powerful prince see ITALY. It was under him that the cathedral of Milan and the Certosa of Pavia were begun. He was the first duke of Milan, having obtained that title from the emperor Wenceslaus. His sons Giovanni Maria, who reigned at Milan (1402–1412), and Filippo Maria, who reigned at Pavia (1402–1447), succeeded him. In 1412, on his brother's death, Filippo united the whole duchy under his sole rule, and attempted to carry out his father's policy of aggrandizement, but without success.

Filippo was the last male of the Visconti house. At his death a republic was proclaimed, which lasted only three years. In 1450 the general Francesco Sforza, who had married Filippo's only child Bianca Visconti, became duke of Milan by right of conquest if by any right. Under this duke the canal of the Martesana, which connects Milan with the Adda, and the Great Hospital were carried out. Francesco was followed by five of the Sforza family. His son Galeazzo Maria (1466–76) left a son, Gian Galeazzo, a minor, whose guardian and uncle Lodovico usurped the duchy (1479–1500). Lodovico was captured in 1500 by Louis XII. of France, and Milan remained for twelve years under the French crown. In the partial settlement which followed the battle of Ravenna, Massimiliano Sforza, a protegé of the emperor, was restored to the throne of Milan, and held it by the help of the Swiss till 1515, when Francis I. of France reconquered the Milanese by the battle of Marignano, and Massimiliano resigned the sovereignty for a revenue from France. This arrangement did not continue. Charles V. succeeded the emperor Maximilian, and at once disputed the possession of the Milanese with Francis. In 1522 the imperialists entered Milan and proclaimed Francesco Sforza (son of Lodovico). Francesco died in 1535, and with him ended the house of Sforza. From this date till the war of the Spanish succession (1714) Milan was a dependency of the Spanish crown. At the close of that war it was handed over to Austria; and under Austria it remained till the Napoleonic campaign of 1796. For the results of that campaign, and for the history of Italian progress towards independence, in which Milan played a prominent part by opening the revolution of 1848, the reader is referred to the article ITALY. The Lombard campaign of 1859, with the battles of Solferino and Magenta, finally made Milan a part of the kingdom of Italy.

Literature.—Pietro Verri, *Storia di Milano*; Corio, *Storia di Milano*; Cantù, *Illustrazione Grande del Lombardo Veneto*; the Milanese chroniclers in Muratori's *Rer. Ital. Scriptores*; Sismondi, *Italian Republics*; Ferrari, *Rivoluzione d' Italia*; Litta, *Famiglie celebri, s.v.* "Torriani," "Visconti," "Sforza," and "Trivulzi;" Muratori, *Annali d'Italia*; Hallam, *History of the Middle Ages*; and *Mediolanum*, 4 vols., 1881. Bonvicino da Riva gives a contemporary account of Milan in the 12th century. (H. F. B.)

MILAZZO, a city of Italy in the province of Messina in Sicily, 20½ miles west of Messina, is built on the eastern shore of the Bay of Milazzo, partly on the isthmus of the promontory, Capo Milazzo, which divides it from the Bay of Olivieri. It consists of an old or upper town protected by strong bastioned walls, and a lower or modern town outside of the enceinte. The fine old castle is now used as a prison. Besides a certain amount of foreign commerce (37 vessels with a burden of 6707 tons entering in 1881, 93 with 13,496 in 1863), Milazzo carries on a good coasting trade (194,366 tons in 1881, 40,138 in 1861), and is one of the seats of the tunny-fishery. The communal population increased from 10,493 in 1861 to 13,565 in 1881, and that of the city was 7427 in 1871.

Milazzo is the ancient Mylæ, a seaport and fortress founded by the Zanclæans (Messanians), which gives its name to the battle of the Mylæan plain in which the Mamertines were defeated by Hiero in 270 B.C. In 1523 it was the scene of an unsuccessful conspiracy to transfer Sicily to the French. Captured by the Germans in 1718, it was besieged by the Spaniards, but relieved by a Neapolitan and English force. In July 1860 the defeat of the Neapolitans in the vicinity, and the seizure of the fortress, formed almost the crowning act of Garibaldi's victorious campaign. The Bay of Milazzo has been the scene of the defeat of the Carthaginian navy by Duilius (260 B.C.), of Pompeius by Octavian's general Agrippa (36 B.C.), and of the French and Messinian galleys by the Pisans (1268).

MILDEW (explained as "meal-dew" or, with more probability, as "honey-dew") is a popular name given to various minute fungi from their appearance, and from the sudden, dew-like manner of their occurrence. Like many other popular names of plants, it is used to denote different species which possess very small botanical affinity. The term is applied, not only to species belonging to various systematic groups, but also to such as follow different modes of life. The corn-mildew, the hop-mildew, and the vine-mildew are, for example, parasitic upon living plants, and the mildews of damp linen and of paper are saprophytes, that is, they subsist on matter which is already dead. It is generally possible to draw a distinct line between parasitic and saprophytic fungi; a species which attacks the living body of its host does not grow on dead matter, and *vice versa*. This is true so far as is known of perhaps all the higher fungi except *Saprolegnia ferax* (Gruith.), a parasite of freshwater fishes (especially of the salmon), which also grows freely on their dead bodies and on those of flies, &c. As regards mildews in general, the conditions of life and growth are mainly suitable nutrition and dampness accompanied by a high temperature. The life-history of the same species of mildew frequently covers two or more generations, and these are often passed on hosts of different kinds. In some cases again the same generation confines its attack to the same kind of host, while in others the same generation grows on various hosts. For information regarding fungi generally see FUNGUS, vol. ix. p. 827.

The following examples are of common occurrence.

The Corn-Mildew (*Puccinia graminis*, Pers., Order *Uredineæ*).—This disease of our grain crops and of many other grass plants is very widely distributed, like its hosts, over the earth, and is by far the most important to man of all mildews. Its life-history is passed in three generations —two of them on the grass plants and one on the barberry. In early spring the first generation is found on the dead leaves and leaf-sheaths of grass plants (in which the disease has hibernated), presenting to the naked eye the appearance of thin black streaks. When examined with a microscope these streaks are seen to consist of a great number of minute two-celled and thick-walled teleutospores (reproductive bodies), each situated at the end of a stalk (see A in fig. 2, vol. ix. p. 831). These have burst through the epidermis of the plant from their origin on threads among the tissues beneath. When they have been in contact with excessive moisture for a few hours, each of the spore-cells germinates by emitting a fine tube called a promycelium, on which there are borne small round thin-walled sporidia (reproductive bodies). The sporidia are easily detached and carried from place to place by the wind, and on alighting on the leaves of a barberry plant

soon germinate by pushing out a small tube which perforates the epidermis and thus gains access to the interior of the leaf, where it branches copiously, and forms a mass of thread-like tissue called mycelium. The germ-tubes of sporidia are unable to enter the leaves, &c., of grass plants. In from six to ten days this mycelium gives rise to flask-shaped bodies called spermogonia (vol. ix. p. 831, fig. 2 B, *sp*), immediately under the surface of the leaf (usually the upper one), but breaking through it at the neck of the flask, out of which there protrudes a bunch of hairs. Within the flasks are formed at the end of stalks many exceedingly small oval bodies called spermatia, which escape through the neck. The function of these bodies has not yet been definitely made out, but that they bear a very striking resemblance to the male sexual organs of other fungi there can be no doubt. In the same leaves and on the same mycelium there arise several days later numerous basin-shaped bodies containing erect stalks, bearing at the apex a number of round æcidiospores (reproductive bodies) in vertical series (vol. ix. p. 831, fig. 2 B, *a*). These constitute the second generation. On their escape they germinate by emitting a tube which, if the host on which they fall be a grass plant, enters the leaf through one of the stomata in the epidermis, and there by branching forms a new mycelium. On this there soon appears, bursting through the epidermis, a new generation consisting of round or oval uredospores produced at the end of stalks (vol. ix. p. 831, fig. 2 C). The uredospores constantly reproduce this generation, and in such abundance that the grain crops are extensively ravaged by its attack. It is in this generation that the term mildew is popularly given to the fungus. Later in autumn on the same mycelium the two-celled teleutospores appear, and these after hibernating renew in spring the life-history. This very remarkable cycle of generations was first traced by Professor de Bary.

The *Hop-Mildew* (*Sphærotheca Castagnei*, Lev., Order *Erysipheæ*) is a parasitic disease of the hop, though it is often to be found on many other plants, such as *Potentilla*, *Spiræa*, *Epilobium*, balsams, cucumbers, dandelions, plantains, &c. The thread-like mycelium appears on the young shoots and leaves of the hop in white spots, which gradually extend and finally unite. This mycelium bears many minute, round conceptacles (perithecia) which with their supporting threads are brown-coloured. Within each perithecium is found a somewhat oval body termed an ascus, containing eight ascospores (reproductive bodies).

The *Vine-Mildew* (*Erysiphe Tuckeri*, Berk., Order *Erysipheæ*) is known only in one generation—called the oidium stage. Soon after the flowering of the vine the attack takes place on the young leaves, from which the thin white mycelium spreads rapidly to the older leaves and twigs, which it does not appear to affect so injuriously. The chief damage is done to the grapes while they are in a very immature condition. The mycelium which travels over the surface sends down at intervals into the tissues short irregular protuberances called haustoria, which perform for it the functions of roots. Above these rise from the mycelium short stalks bearing each a single oval spore at the apex. The disease spreads on the same plant not only by the extension of the mycelium but by the scattering and germination of the spores. Here no perithecia are known.

The *Paper-Mildew* (*Ascotricha chartarum*, Berk., Order *Erysipheæ*) grows on damp paper, and therefore is saprophytic in its mode of life. It consists at first of a branching filamentous mycelium on which minute globular spores occur. Finally a round brown perithecium is formed among the threads which appear as radiating from it. Within the perithecium are numerous linear asci containing each a row of dark elliptic ascospores.

For the *Erysipheæ* generally see FUNGUS, vol. ix. p. 833.

MILETUS, an ancient city on the southern shore of the Latmic Gulf opposite the mouth of the Mæander. Before the Ionic migration it was inhabited by the Carians (*Iliad* ii. 876; Herod. i. 146); other authorities call the original people Leleges, who are always hard to distinguish from Carians. The Greek settlers from Pylus under Neleus massacred all the men in the city, and built for themselves a new city on the coast. It occupied a very favourable situation at the mouth of the rich valley of the Mæander, and was the natural outlet for the trade of southern Phrygia (Hipponax, *Fr.* 45); it had four harbours, one of considerable size. Its power extended inland for some distance up the valley of the Mæander, and along the coast to the south, where it founded the city of Iasus. The trade with the Black Sea, however, was the greatest source of wealth to the Ionian cities. Miletus like the rest turned its attention chiefly to the north, and after a time it succeeded in almost monopolizing the traffic. Along the Hellespont, the Propontis, and the Black Sea coasts it founded more than sixty cities—among them Abydus, Cyzicus, Sinope, Dioscurias, Panticapæum, and Olbia. All these cities were founded before the middle of the 7th century; and before 500 B.C. Miletus was decidedly the greatest Greek city. During the time when the enterprise and energy of the seafaring population, the ἀειναῦται, raised Miletus to such power and wealth, nothing is known of its internal history. The analogy of all Greek cities, and some casual statements in later writers, suggest that the usual bloody struggles took place between the oligarchy and the democracy, and that tyrants sometimes raised themselves to supreme power in the city; but no details are known. Miletus was equally distinguished at this early time as a seat of literature. The Ionian epic and lyric poetry indeed had its home farther north; philosophy and history were more akin to the practical race of Miletus, and Thales, Anaximander, Anaximenes, Hecatæus, all belonged to this city. The three Ionian cities of Caria—Miletus, Myus, and Priene—spoke a peculiar dialect of Ionic.[1]

When the Mermnad kings raised Lydia to be a great military kingdom, Miletus was their strongest adversary. War was carried on for many years, till Alyattes concluded a peace with Thrasybulus, tyrant of Miletus; the Milesians afterwards seem to have peaceably acknowledged the rule of Crœsus. On the Persian conquest Miletus passed under a new master; it headed the revolt of 500 B.C., and was taken by storm after the battle of Lade. Darius treated it with peculiar severity, massacred most of the inhabitants, transported the rest to Ampe at the mouth of the Tigris, and gave up the city to the Carians. Henceforth the history of Miletus has no special interest; it revived indeed when the Persians were expelled from the coast in 479 B.C., and was a town of commercial importance throughout the Græco-Roman period, when it shared in the general fortunes of the Ionian cities under the rule of Athenians, Persians, Macedonians, Pergamenians, and Romans in succession. Its harbours, once protected by Lade and the other Tragusæan islands, were gradually silted up by the Mæander, and Lade is now a hill some miles from the coast. Ephesus took its place as the great Ionian harbour in the Hellenistic and Roman times. It was the seat of a Christian bishopric, but its decay was sure, and its site is now a marsh.

See Schroeder, *Comment. de Reb. Miles.*; Soldan, *Rer. Miles. Comment.*; Rayet, *Milet et le Golfe Latmique*; Head, "Early Electrum Coins," in *Numism. Chron.*, vol. xvi.

MILFORD, a seaport, market-town, and contributory parliamentary borough (one of the Pembroke district) of Pembrokeshire, South Wales, is finely situated on the north side of Milford Haven, about 8 miles west-north-west of Pembroke. The land-locked estuary of Milford Haven stretches about 10 miles inland, with a

[1] The coinage of Miletus during this early period is an important subject on account of the wide commercial connexions of the city. The early electrum coinage belongs to the Phœnician or Græco-Asiatic standard, which was introduced from Phœnicia and spread over many of the Ionian and Thracian cities through the influence of Milesian trade. Very archaic coins of Miletus, Ephesus, Cyme, and Sardis are known of this standard, and at a somewhat later date of Chios, Samos, Clazomenæ, Lampsacus, Abydus, and Cyzicus. The lion is the regular Milesian type, often with a star beside or above him.

breadth of from 1 to 2 miles. In most places it has a depth of from 15 to 19 fathoms, and, as it is completely sheltered by hills, vessels can ride in it at anchor in all kinds of weather. The royal dockyard, founded at Milford in 1790, was removed in 1811, and from that time trade has been in a languishing condition. The town possesses iron-works. The shipping trade is confined chiefly to coasting vessels, but with the completion of new docks, capable of receiving vessels of the largest tonnage, it is supposed that a considerable trade may be carried on with America. The population of the urban sanitary district in 1871 was 3252, and in 1881 it was 3813.

MILFORD, a post-village of the United States, in Worcester county, Massachusetts, lies 34 miles south-west of Boston, at the junction of the Milford branch of the Boston and Albany Railroad with the Hopkinton, Milford, and Woonsocket Railroad. It is one of the principal seats of the boot manufacture in New England, and also produces large quantities of straw goods. The population was 9310 in 1880.

MILICZ, or MILITSCH, of Kremsier, Moravia, was the most influential among those preachers and writers in Moravia and Bohemia who during the 14th century paved the way for the reforming activity of Huss and through him for that of Luther. He was born about 1325, was already in holy orders in 1350, in 1360 was attached to the court of the emperor Charles IV., whom he accompanied into Germany in that year, and about the same time also held a canonry in the cathedral of Prague along with the dignity of archdeacon. About 1363 he resigned all his appointments that he might become a preacher pure and simple; he addressed scholars in Latin, and (an innovation) the laity in their native Czech, or in German, which he acquired for the purpose. The success of his labours in reclaiming the fallen made itself apparent in the reformation of a whole quarter of the city of Prague. As he dwelt more and more on ecclesiastical abuses and the corruption of the clergy, and viewed them in the light of Scripture, the conviction grew in his mind that the "abomination of desolation" was now seen in the temple of God, and that antichrist had come, and in 1367 he went to Rome (where Urban V. was expected from Avignon) to expound these views. He affixed to the gate of St Peter's a placard announcing his sermon, but before he could deliver it was thrown into prison by the Inquisition. Urban, however, on his arrival ordered his release, whereupon he returned to Prague, and from 1369 to 1372 preached daily in the Teyn Church there. In the latter year the clergy of the diocese complained of him to the papal court at Avignon, whither he was summoned in Lent 1374, and where he died before his case was decided. He was the author of a *Libellus de Antichristo*, written in prison at Rome, a series of *Postillæ* and *Lectiones Quadragesimales* in Latin, and a similar series of *Postils* in Czech.

MILITARY FRONTIER (German, *Militärgrenze*; Slavonic, *Granitza*), a narrow strip of Austrian-Hungarian territory stretching along the borders of Turkey, which had for centuries a peculiar military organization, and from 1849 to 1873 constituted a crown-land. As a separate division of the monarchy it owed its existence to the necessity of maintaining during the 15th, 16th, and 17th centuries a strong line of defence against the invasions of the Turks, and may be said to have had its origin with the establishment of the captaincy of Zengg by Matthias Corvinus and the introduction of Uskoks (fugitives from Turkey) into the Warasdin district by the emperor Ferdinand I. By the close of the 17th century there were three frontier "generalates"—Carlstadt, Warasdin, and Petrinia (the last also called the Banal). After the defeat of the Turkish power by Prince Eugene it was proposed to abolish the military constitution of the frontier, but the change was successfully resisted by the inhabitants of the district; on the other hand, a new Slavonian frontier district was established in 1702, and Maria Theresa extended the organization to the march-lands of Transylvania (the Szekler frontier in 1764, the Wallachian in 1766).[1]

As a reward for the service it rendered the Government in the suppression of the Hungarian insurrection in 1848, the Military Frontier was erected in 1849 into a crown-land, with a total area of 15,182 square miles, and a population of 1,220,503. In 1851 the Transylvanian portion (1177 square miles) was incorporated with the rest of Transylvania; and in 1871 effect was given to the imperial decree of 1869 by which the districts of the Warasdin regiments (St George and the Cross) and the towns of Zengg, Belovar, Ivanič, &c., were "provincialized" or incorporated with the Croatian-Slavonian crown-land. In 1872 the Banat regiments followed suit; and in 1873 the old military organization was abolished in all the rest of the frontier. Not till 1881, however, were the Croatian-Slavonian march-lands completely merged in the kingdoms to which they naturally belonged.

The social aspect of the military frontier régime is interesting. A communal system of land tenure natural to the old Slavonians was artificially kept in existence. The mark or plot of ground assigned to the original family of settlers remained the property of the family as such, and could not be portioned out among the several members. In this way the house-community, all under the rule of the same house-father and house-mother (who were not necessarily man and wife, nor the oldest members of the community), and all living within the same palisade, sometimes came to number two or three hundred persons. The "family" dined in a common hall, and after dinner discussed and settled matters affecting the common weal. Every man possessing real property in the country, and capable of bearing arms, was liable to military service from his twentieth year. The house-communities are now beginning to avail themselves of the permissive partition laws, and strangers are free to come and acquire property in land. Watch-towers with wooden clappers and the beacons which flashed the alarm along the whole frontier in a few hours are still features in the landscape.

MILITARY LAW consists of the statutes, rules of procedure, royal warrants, and orders and regulations which prescribe and enforce the public obligations of the officers, soldiers, and others made subject to its provisions. Its essential purpose is the maintenance of discipline; but it also includes the administrative government of the military forces of the state, more especially in the matters of enlistment, service, and billeting. The term "martial law" sometimes applied to it is, as regards modern times at least, a misnomer. For martial law as it is now understood applies not only to military persons but to the civil community, and may be described generally as the abrogation of ordinary law and the substitution for it of military force uncontrolled save by what, in the discretion of the commanding general, may be considered the necessity of the case.

The military law of England in early times existed, like the forces to which it applied, in a period of war only.

[1] By 1848 the following had come to be the division of the Military Frontier:—(1) *The Carlstadt (Carlowitz), Warasdin, and Banal Generalate*: the Licca Regiment (headquarters at Gospich), the Ottochaz Regiment (Ottochaz), the Ogulin (Ogulin), the Sluin (Carlstadt), the Cross (Belovar), the St George's (Belovar), the 1st Banal (Glina), the 2d Banal (Petrinia). (2) *The Slavonian Generalate*: the Gradiska Regiment (Neu Gradiska), the Brood Regiment (Vinkovcze), the Peterwardein (Mitrovicz), the Tchaikist Battalion (Titel). (3) *The Banat Generalate*: the German Banat Regiment (Pancsova), the Wallachian Banat (Karansebes), the Illyrian Banat (Weisskirchen). (4) *The Transylvanian Generalate*: The Szekler Regiment No. 14 (Csik Szereda), the Szekler Regiment No. 15 (Keszdi Vasarhely), the Wallachian No. 16 (Orlath), the Wallachian No. 17 (Naszod). Twelve towns, known as "military communities," had communal constitutions not unlike those of the free towns of Hungary—Carlopago, Zengg, Petrinia, Kostainicza, Belovar, Ivanič, Brood, Peterwardein, Carlowitz, Semlin, Pancsova, and Weisskirchen.

Troops were raised for a particular service, and were disbanded upon the cessation of hostilities. The crown, of its mere prerogative, made laws known as Articles of War, for the government and discipline of the troops while thus embodied and serving. Except for the punishment of desertion, which offence was made a felony by statute in the reign of Henry VI., these ordinances or Articles of War remained almost the sole authority for the enforcement of discipline until 1689, when the first Mutiny Act was passed and the military forces of the crown were brought under the direct control of parliament. Even the Parliamentary forces in the time of Charles I. and Cromwell were governed, not by an Act of the legislature, but by articles of war similar to those issued by the king and authorized by an ordinance of the Lords and Commons, exercising in that respect the sovereign prerogative. This power of law-making by prerogative was, however, held to be applicable during a state of actual war only, and attempts to exercise it in time of peace were ineffectual. Subject to this limitation it existed for considerably more than a century after the passing of the first Mutiny Act. From 1689 to 1803, although in peace time the Mutiny Act was occasionally suffered to expire, a statutory power was given to the crown to make Articles of War to operate in the colonies and elsewhere beyond the seas in the same manner as those made by prerogative operated in time of war. In 1715, in consequence of the rebellion, this power was created in respect of the forces in the kingdom. But these enactments were apart from and in no respect affected the principle acknowledged all this time that the crown of its mere prerogative could make laws for the government of the army in foreign countries in time of war. The Mutiny Act of 1803 effected a great constitutional change in this respect: the power of the crown to make any Articles of War became altogether statutory, and the prerogative merged in the Act of Parliament. So matters remained till the year 1879, when the last Mutiny Act was passed and the last Articles of War were promulgated. The Mutiny Act legislated for offences in respect of which death or penal servitude could be awarded, and the Articles of War, while repeating those provisions of the Act, constituted the direct authority for dealing with offences for which imprisonment was the maximum punishment as well as with many matters relating to trial and procedure. The Act and the Articles were found not to harmonize in all respects. Their general arrangement was faulty, and their language sometimes obscure. In 1869 a royal commission recommended that both should be recast in a simple and intelligible shape. In 1878 a committee of the House of Commons endorsed this view and made certain recommendations as to the way in which the task should be performed. In 1879 the Government submitted to parliament and passed into law a measure consolidating in one Act both the Mutiny Act and the Articles of War, and amending their provisions in certain important respects. This measure was called the "Army Discipline and Regulation Act, 1879." After one or two years' experience of its working it also was found capable of improvement, and was in its turn superseded by the Army Act, 1881, which now forms the foundation and the main portion of the military law of England. It contains a proviso saving the right of the crown to make Articles of War, but in such a manner as to render the power in effect a nullity; for it enacts that no crime made punishable by the Act shall be otherwise punishable by such Articles. As the punishment of every conceivable offence is provided for by the Act, any Articles made thereunder can be no more than an empty formality having no practical effect. Thus the history of English military law up to 1879 may be divided into three periods, each having a distinct constitutional aspect:—(1) that prior to 1689, when the army, being regarded as so many personal retainers of the sovereign rather than servants of the state, was mainly governed by the will of the sovereign; (2) that between 1689 and 1803, when the army, being recognized as a permanent force, was governed within the realm by statute and without it by the prerogative of the crown; and (3) that from 1803 to 1879, when it was governed either directly by statute or by the sovereign under an authority derived from and defined and limited by statute. Although in 1879 the power of making Articles of War became in effect altogether inoperative, the sovereign was empowered to make rules of procedure, having the force of law, which regulate the administration of the Act in many matters formerly dealt with by the Articles of War. These rules, however, must not be inconsistent with the provisions of the Army Act itself, and must be laid before parliament immediately after they are made. Thus in 1879 the government and discipline of the army became for the first time completely subject either to the direct action or the close supervision of parliament.

A further notable change took place at the same time. The Mutiny Act had been brought into force on each occasion for one year only, in compliance with the constitutional theory that the maintenance of a standing army in time of peace, unless with the consent of parliament, is against law. Each session therefore the text of the Act had to be passed through both Houses clause by clause and line by line. The Army Act, on the other hand, is a fixed permanent code. But constitutional traditions are fully respected by the insertion in it of a section providing that it shall come into force only by virtue of an annual Act of Parliament. This annual Act recites the illegality of a standing army in time of peace unless with the consent of parliament, and the necessity nevertheless of maintaining a certain number of land forces (exclusive of those serving in India) and a body of royal marine forces on shore, and of keeping them in exact discipline, and it brings into force the Army Act for one year.

Military law is thus chiefly to be found in the Army Act and the rules of procedure made thereunder, the Militia Act, 1882, the Reserve Forces Act, 1882, and the Volunteer Act, 1863, together with certain Acts relating to the yeomanry, and various royal warrants and regulations. The Army Act itself is, however, the chief authority. Although the complaint has been sometimes made, and not without a certain amount of reason, that it does not accomplish much that it might in point of brevity, simplicity, and clearness of expression, it is a very comprehensive piece of legislation, and shows some distinct improvements upon the old Mutiny Acts and Articles of War.

The persons subject to military law are the officers on the active list and the soldiers of the regular forces (including the royal marines), the permanent staff of the auxiliary (*i.e.*, the militia, volunteer, and yeomanry) forces, and the officers of the militia. The above persons are amenable to its provisions at all times except while embarked on board a commissioned ship of the royal navy, when they become subject to the Naval Discipline Act and certain orders in council made under its authority. Those who are subject to military law in certain circumstances only are—officers and men while serving in a force raised out of the United Kingdom and commanded by an officer of the regular forces; pensioners when employed in military service under the command of a regular officer; the non-commissioned officers and men of the militia, during training, when attached to the regulars or when permanently embodied; the officers of the yeomanry and the volunteers when in command of or attached to a body of men subject to military law, or when their corps is on actual military

service, or when ordered on duty with their own consent; the men of the yeomanry when they or their corps are being trained, when they are attached to or acting with the regular forces, when their corps is on actual military service, or when serving in aid of the civil power; the men of the volunteers when they are being trained with or are attached to any body of troops, or when their corps is on actual military service; the men of the army reserve and the militia reserve when called out for training or on duty in aid of the civil power; any person who in an official capacity equivalent to that of an officer accompanies a body of troops on active service beyond the seas; any person accompanying a force on active service holding a pass from the general entitling him to be treated on the footing of an officer. In this last category would of course be included newspaper correspondents, also sutlers and followers. In one or two cases persons are subjected to military law to a limited extent and in respect only of certain offences. Thus a militiaman even when not out for training or not embodied is liable to a military trial and punishment for fraudulent enlistment or making a false answer on attestation. In the same manner an army reserve man may be tried and punished by court martial for neglect to appear at the place where he is bound periodically to report himself, or for insubordination to his superiors on these occasions, or for any fraud in connexion with the receipt of his pay. A man of the army reserve or the militia reserve has the legal status of and in fact becomes a regular soldier when called out on occasions of national danger or emergency under the sovereign's proclamation.

When a person subject to military law commits an offence he is taken into military custody, which means either arrest in his own quarters or confinement. He must without unnecessary delay be brought before his commanding officer, who upon investigating the case may dismiss the charge if in his discretion he thinks it ought not to be proceeded with, or may take steps to bring the offender before a court martial. Where the offender is not an officer he may dispose of the case summarily, the limit of his power in this respect being seven days' imprisonment with hard labour, fines not exceeding 10s. for drunkenness, certain deductions from pay, confinement to barracks for twenty-eight days, this involving severe extra drills, deprivations, and other minor punishments. Where the offence is absence without leave for a period exceeding seven days, the commanding officer may award a day's imprisonment in respect of each day of such absence up to twenty-one. It is only in the case of the imprisonment exceeding seven days that the evidence before the commanding officer is taken on oath, and then only in the event of the accused so desiring it. The commanding officer is enjoined by regulation not to punish summarily the more serious kind of offences, but his legal jurisdiction in this respect is without limit as regards any soldier brought before him, and when he has dealt summarily with a case the accused is free from any other liability in respect of the offence thus disposed of. In any instance where the commanding officer has summarily awarded imprisonment, fine, or deduction from pay, the accused may claim a district court martial instead of submitting to the award.

Ordinary courts martial are of three kinds, viz.:—(1) a regimental court martial, usually convened and confirmed by the commanding officer of the regiment or detachment, presided over by an officer not under the rank of captain, composed of at least three officers of the regiment or detachment with not less than one year's service, and having a maximum power of punishment of forty-two days' imprisonment with hard labour; (2) a district court martial, usually convened by the general of the district, consisting in the United Kingdom, India, Malta, and Gibraltar of not less than five and elsewhere of not less than three officers, each with two years' service or more, and having a maximum power of punishment of two years' imprisonment with hard labour; (3) a general court martial, the only tribunal having authority to try a commissioned officer, and with a power of punishment extending to death or penal servitude, for offences for which these penalties are authorized by statute; it consists of not less than nine officers in the United Kingdom, India, Malta, and Gibraltar and of five elsewhere, each of whom must have over three years' service, five being not under the rank of captain. There is another kind of tribunal incidental to service in the field, or where, in the case of an offence against the person or property of an inhabitant, an ordinary court martial cannot be held, namely, a field general court martial. This court may consist of three officers only, and it has the power of sentencing to death. Another kind of court, called a summary court martial, may be held where an offence has been committed upon active service and an ordinary court cannot be conveniently assembled. In the event of three officers not being available it may consist of two. When thus constituted it can award only a "summary punishment" or imprisonment; where it consists of three officers, however, it can sentence to death. In the case of a field general or a summary court martial many forms and precautions prescribed in the case of ordinary courts are not necessarily observed, the whole proceeding being from the necessity of the case a somewhat rough and ready means of dealing promptly with crime.

The Army Act prescribes the maximum punishment which may be inflicted in respect of each offence. That of death is incurred by various acts of treachery or cowardice before the enemy, or by when on active service interfering with or impeding authority, leaving without orders a guard or post, or when sentry sleeping or being drunk on a post, plundering or committing an offence against the person or property of an inhabitant, intentionally causing false alarms, or deserting. Whether upon active service or not, a soldier also becomes liable to the punishment of death who mutinies or incites to or joins in or connives at a mutiny, who uses or offers violence to or defiantly disobeys the lawful command of his superior officer when in the execution of his office. Penal servitude is the maximum punishment for various acts and irregularities upon active service not distinctly of a treacherous or wilfully injurious character, for using or offering violence or insubordinate language to a superior, or disobeying a lawful command when upon active service. The same punishment is applicable when not upon active service to a second offence of desertion or fraudulent enlistment (*i.e.*, enlistment by one who already belongs to the service), certain embezzlements of public property, wilfully releasing without authority a prisoner or wilfully permitting a prisoner to escape, enlisting when previously discharged from the service with disgrace without disclosing the circumstances of such discharge, or any other offence which by the ordinary criminal law of England is punishable with penal servitude. Imprisonment with hard labour for two years is the maximum punishment for minor forms and degrees of those offences which if committed upon active service would involve death or penal servitude, such as using or offering violence or insubordinate language to a superior or disobeying a lawful command, and for the following offences:—resisting an escort, breaking out of barracks, neglect of orders, a first offence of desertion or attempted desertion or aiding or conniving at desertion, or of fraudulent enlistment, absence without leave, failure to appear at parade, going beyond prescribed bounds, absence from school, malingering or producing disease or infirmity, maiming with intent to render a soldier unfit for service, an act of a fraudulent nature, disgraceful conduct of a cruel, indecent, or unnatural kind, drunkenness, releasing a prisoner without proper authority or allowing him to escape, being concerned in the unreasonable detention of a person awaiting trial, escaping or attempting to escape from lawful custody, conniving at exorbitant exactions, making away with, losing by neglect, or wilfully injuring military clothing or equipments, ill-treating a horse used in the service, making false or fraudulent representations in public documents, making a wilfully false accusation against an officer or soldier, making a false confession of desertion or fraudulent enlistment, or a false statement in respect of the prolongation of furlough, misconduct as a witness before a court martial or contempt of such court, giving false evidence on oath, any offence specified in relation

to billeting or the impressment of carriages, making a false answer to a question put upon attestation, being concerned in unlawful enlistment, using traitorous or disloyal words regarding the sovereign, disclosing any circumstance relating to the numbers, position, movements, or other circumstances of any part of her majesty's forces so as to produce effects injurious to her majesty's service, fighting or being concerned in or conniving at a duel, attempting suicide, obstructing the civil authorities in the apprehension of any officer or soldier accused of an offence, any conduct, disorder, or neglect to the prejudice of good order and military discipline, any offence which if committed in England would be punishable by the law of England. There is another offence which can be committed by officers only, namely, "scandalous conduct unbecoming the character of an officer and a gentleman." It necessitates cashiering, a punishment which in the case of an officer may be awarded as an alternative to imprisonment in several other instances. There is also an offence peculiar to officers and non-commissioned officers, that of striking or ill-treating a soldier or unlawfully detaining his pay. A sentence of cashiering as distinguished from that of dismissal in the case of an officer involves an incapacity to serve the crown again. An officer may be also sentenced to forfeiture of seniority of rank and to reprimand or severe reprimand. A non-commissioned officer may be sentenced to be reduced to a lower grade or to the ranks, and where sentenced to penal servitude or imprisonment is deemed to be reduced to the ranks. The commander-in-chief at home or the commander-in-chief in India or in either of the presidencies may also cause a non-commissioned officer to be reduced to a lower grade or to the ranks. An acting non-commissioned officer may be ordered by his commanding officer for an offence or for inefficiency or otherwise to revert to his permanent grade,—in other words, to forfeit his acting rank.

It will have been observed that persons subject to military law are liable to be tried by court martial for offences which if committed in England would be punishable by the ordinary law, and to suffer either the punishment prescribed by the ordinary criminal law or that authorized for soldiers who commit offences to the prejudice of good order and military discipline. The effect of the latter alternative is that for many minor offences for which a civilian is liable to a short term of imprisonment, or perhaps only to a fine, a soldier may be awarded two years' imprisonment with hard labour. A court martial, however, cannot take cognizance of the crimes of treason, murder, manslaughter, treason-felony, or rape if committed in the United Kingdom. If one of these offences be committed in any place within her majesty's dominions other than the United Kingdom or Gibraltar, a court martial can deal with it only if it be committed on active service or in a place more than 100 miles from a civil court having jurisdiction to try the offence. With regard to all civil offences the military law, it is to be understood, is subordinate to the ordinary law, and a civilian aggrieved by a soldier in respect of a criminal offence against his property or person does not forfeit his right to prosecute the soldier as if he were a civilian.

The crimes for which soldiers are most usually tried are desertion, absence without leave, loss of necessaries, violence or insubordination to superiors, drunkenness, and various forms of conduct to the prejudice of discipline. The punishments are generally speaking gauged as much with regard to the character and antecedents of the prisoner as to the particular offence. For a first offence of an ordinary kind a district court martial would give as a rule fifty-six days' imprisonment with hard labour, for a second or graver crime eighty-four days. There are not many instances in which the period of imprisonment exceeds six months. Corporal punishment, which had been practically limited to offences committed upon active service, and in 1879 to crimes punishable with death, was finally abolished in 1881, and a summary punishment substituted. This summary punishment includes the liability for a term of three months to be kept in iron-fetters and handcuffs, and while so kept to be attached to a fixed object so that the offender may remain in a fixed position for a period not exceeding two hours in the day for not more than three out of any four consecutive days and for not more than twenty-one days in the aggregate. The offender may also be subjected to the like labour and restraint, and may be dealt with in the same manner as if sentenced to hard-labour imprisonment. But these summary punishments are to be inflicted so as not to cause injury to health or leave a permanent mark on the offender. The first instances in which this kind of punishment was inflicted occurred during the campaign of 1882 in Egypt. Estimated by the results, the abolition of flogging does not appear to have injuriously affected discipline, the conduct of the troops in Egypt having been exceptionally good. The practice of marking a soldier with the letters "D" (deserter) or "BC" (bad character), in order to prevent his re-enlistment, was abolished about a dozen years ago in deference to public opinion, which erroneously adopted the idea that the "marking" was effected by red-hot irons or in some other manner involving torture. Military men for the most part regret its abolition, and maintain that if the practice were still in force the army would not be tainted by the presence of many bad characters who find means of eluding the vigilance of the authorities and enlisting after previous discharge.

The course of procedure in military trials is as follows. When a soldier is remanded by his commanding officer for trial by a district or general court martial, a copy of the charge, together with the statements of the witnesses for the prosecution (called the summary of evidence), is furnished to him, and he is given proper opportunity of preparing his defence, of communicating with his witnesses or legal adviser, and of procuring the attendance of his witnesses. Further, if he desires it, a list of the officers appointed to form the court shall be given him. Any officer is disqualified to sit as a member who has convened the court, who is the prosecutor or a witness for the prosecution, who has made the preliminary inqury into the facts, who is the prisoner's commanding officer, or who has a personal interest in the case. The prisoner may also object to any officer on the ground of bias or prejudice similarly as a civilian might challenge a juror. Except as regards the delay caused by the writing out of the evidence, the procedure at a court martial is very much the same as that at an ordinary criminal trial,—the examination and cross-examination of the witnesses, addresses of the prosecutor and prisoner, and the rules governing the admission or rejection of evidence being nearly identical. At a general court martial, and sometimes at a district court, a judge advocate representing the judge advocate general officiates, his functions being very much those of a legal assessor to the court. He advises upon all points of law, and sums up the evidence just as a judge charges a jury. When the prisoner pleads guilty the court finds a verdict accordingly, reads the summary of evidence, hears any statement in mitigation of punishment, and takes evidence as to character before proceeding to pass sentence. The sentence is that of the majority of the court, except where death is awarded, when two-thirds of the members in the case of a general court martial and the whole in that of a field general court martial must concur. When an acquittal upon all the charges takes place the verdict is announced in open court, and the prisoner is released without any further proceeding. When the finding is "guilty," evidence as to character is taken, and the court deliberates in private upon the sentence, but the result is not made known until the proceedings are confirmed and promulgated. No conviction or sentence has any effect until it is thus confirmed by the proper authority. The confirming authority in the case of a regimental court is the commanding officer, in that of a district court martial the general officer commanding the district, and in that of a general court, if held in the United Kingdom her majesty, and if abroad in most cases the general officer commanding. The confirming authority may order the reassembling of the court in order that any question or irregularity may be revised and corrected, but not for the purpose of increasing a sentence. He may, however, of his own discretion, and without further reference to the court, refuse confirmation to the whole or any portion of the finding or sentence, and he may mitigate, commute, or entirely remit the punishment. In the case of a general court martial the proceedings are sent to the judge advocate general, who submits to the queen his opinion as to the legality of the trial and sentence. If they are legal in all respects he sends the proceedings to the commander-in-chief, upon whom rests the duty of advising the queen regarding the exercise of clemency. In addition to confirmation, however, every general or district court martial held out of India has another ordeal to go through. It is reviewed and examined in the office of the judge advocate general, and any illegality that may be disclosed is corrected and the prisoner is relieved of the consequences. To a certain extent a protection against illegality also exists in the case of regimental courts martial. A monthly return of those held in each regiment is laid before the general commanding the district or brigade, by whom any question that might appear to him doubtful would be referred to the adjutant general or the judge advocate general for decision. It is to be noted, however, that the judge advocate general, although fulfilling duties which are in their nature judicial, is only an adviser. He is not actually a judge in an executive sense, and has no authority directly to interfere with or correct an illegal conviction. In many cases the law thus provides no remedy for an officer or soldier who may have been wronged by the finding or sentence of a court martial,—for instance, through a verdict not justified by the evidence or through a non-observance of the rules and practice prescribed for these tribunals. A person who has suffered injustice may appeal to the Queen's Bench division of the high court of justice. But, speaking generally, that tribunal would not interfere with a court martial exercising its jurisdiction within the law as regards the prisoner, the crime, and the sentence. In most cases, therefore, the virtual protector of an accused person against illegality is the judge advocate general, who personally advises the queen and the military authorities that the law shall be complied with. As a privy councillor and member of the House of Commons that officer is responsible both to the queen and to parliament for the right and due administration of military law; and, notwithstanding his want of direct executive authority, it is not to be contemplated that any military officer would hesitate to act upon advice given by him with reference to a

legal question connected with a court martial. The department of the judge advocate general consists of the judge advocate general, who is a lawyer, a privy councillor, and a member of parliament, of a permanent deputy judge advocate general who is also a lawyer, and of three military officers as deputy judge advocates having special experience in the working of military law.

The Army Act applies to European officers and soldiers serving in India in the same manner as to the rest of the army, but natives of India are governed by their own Articles of War, and in the case of civil offences they are dealt with according to the provisions of the Indian penal code. The department of the judge advocate general in India is distinct from and independent of that of the judge advocate general of the army, and courts martial held in that country are not subject to the supervision of a professional lawyer. Certain prominent irregularities led to the appointment of a barrister as judge advocate general in India in 1869, but after a few years that appointment again became filled by a military officer. The staff of the department is, however, far more numerous in India than elsewhere. There are judge advocates general for each of the presidencies, and a deputy judge advocate at each of the more important military centres.

Statistics of Crime in the Army.—Commissioned officers are rarely subjected to trial by court martial. Where an officer commits himself in a military sense, and his misconduct is too serious to be passed over merely with a mark of official displeasure, he is usually given and seldom fails to accept the alternative of resigning his commission. In some instances the crown is advised to exercise its prerogative and remove him from the army on the ground that her majesty has no further occasion for his services. In no circumstances can an officer or soldier claim a court martial as a right. In the result, the annual number of trials of officers does not average more than four of late years. Among the non-commissioned officers and soldiers of the army, however, the trials and summary punishments by commanding officers are exceedingly numerous, as will presently be seen. In India this observation hardly holds good, for in that country desertion is physically almost impossible except at the two or three seaports where troops are stationed. Absence without leave is for a similar reason of rare occurrence, while the fact of the troops living in their own cantonments, and being free from many temptations of life existing in the large towns and garrisons at home, places them outside the influence of certain prevalent causes of crime. For this reason mainly the proportion of courts martial held in 1881 was 107 per 1000 men at home as compared with 76 abroad. Similarly the proportion of minor punishments per 1000 was 1449 at home to 1042 abroad. It is also generally found that men engaged upon active service in the field commit less crime than those serving in ordinary circumstances. But the general criminal statistics of the army for 1881 show a formidable amount of crime and punishment. Upon an average strength of 181,186 non-commissioned officers and men there were 16,523 courts martial, of which 179 were general, 8549 district, and 7795 regimental courts. There were also 224,681 minor punishments by commanding officers, including 44,108 fines for drunkenness. These figures generally show an increase of crime as compared with the two years immediately preceding, but these two exhibited a decrease upon previous years. Of the offences tried by court martial in 1881 the following were the principal:—mutiny 7, desertion 1597, offences in relation to enlistment (fraudulently enlisting while already belonging to the service or making false answers upon attestation) 1190, violence to and disobedience of superiors 1650, minor insubordination and neglect of orders 1472, quitting or sleeping on post 681, drunkenness on duty 2661, drunkenness (tried by court martial when the offence has been committed on a fifth occasion within twelve months) 2147, disgraceful conduct of various kinds 660, absence without leave not amounting to desertion 3293, making away with or losing by neglect equipment or necessaries 3768, and miscellaneous offences chiefly of an ordinary criminal character or to the prejudice of discipline 4181. Upon the 16,523 trials there were 349 findings of acquittal. Regarding the punishments awarded, it appears that no soldier was sentenced to death during the year, and the other awards were as follows:—penal servitude 104, imprisonment with or without hard labour (almost invariably the former) 12,125, discharge with ignominy without other punishment 42, stoppages of pay without other punishment 65, flogging (before the abolition of that punishment by the Act of 1881) 15, and the new summary punishment (authorized as a substitute for flogging) 3. Of the non-commissioned officers 3228 were punished by reduction to a lower grade or to the ranks, while 591 more suffered imprisonment in addition to loss of grade, the former number being in the proportion of about 12 and the latter of 2 per cent. to strength. Of the men tried 305 were pardoned.

Military Law of other Countries.—The administration of military law in other countries having large armies harmonizes in many important respects with that of England. In some indeed it is a question whether their systems are not superior and in advance. They have a considerable body of "auditors" or military lawyers who expound the law and do much to secure a uniform and exact administration of justice. Thus in Austria there are about five hundred of these auditors, one being attached to each regiment. In the same country there are also courts of appeal from the courts of first instance, these latter consisting of eight persons including the auditor. Where the prisoner is a non-commissioned officer or a private, that rank is represented on the court. Here also the confirmation of superior authority is required. In the German army there are general and regimental courts. An auditor who is a lawyer is attached to each division, and it is his duty to expound the law, collect the evidence, and read it to the court in the presence of the prisoner, who is asked if he has any thing to say. The court consists of eleven members, of whom upon the trial of a private soldier or non-commissioned officer three are of the rank of the accused. The power of commanding officers in regard to disciplinary punishments is greater than in the British army, especially in relation to officers, who may be placed in arrest for fourteen days. The non-commissioned officers and privates are liable to extra guards, drills, fatigues, and different degrees of arrest, some of a very severe character. Dismissal from the army, which is regarded as a most severe punishment, involving civil disgrace, is often awarded. In Russia there are three kinds of military courts—namely, the regimental court martial, the tribunals of military districts, and the supreme tribunal at St Petersburg. They are permanent courts, are attended by legal persons, and in certain instances have jurisdiction over the civil population as well as the army. There is a judge advocate general at St Petersburg, where the supreme tribunal consists of general officers and high war-office functionaries who have studied military law or possess a large experience of its working. In Italy there are permanent military tribunals for the trial of non-commissioned officers and soldiers, while special tribunals are appointed to try officers. The court is the absolute judge of the facts, but regarding legal errors or irregularities an appeal lies to the supreme war tribunal, which consists of four civilian judges and three general officers. The French code corresponds in many respects with those of the other great Continental armies, but it tends rather to give individual officers large powers of imprisonment graduated according to their rank. The chief distinctive feature of the French system is the institution of regiments of discipline for refractory characters. When the general officer's power of imprisonment (two months) is exhausted the offender may be sent before a court of discipline and by them drafted into a *compagnie de discipline*; and cases of habitual misconduct are thus dealt with, the man being struck off the strength of his original corps and transferred to one in Algeria. The military law of the United States is founded upon and proceeds much upon the same lines as that of England. (J. C. O'D.)

MILITARY TACTICS. See WAR.

MILITIA. The militia of the United Kingdom consists of a number of officers and men maintained for the purpose of augmenting the military strength of the country in case of imminent national danger or great emergency. In such a contingency the whole or any part of the militia is liable, by proclamation of the sovereign, to be embodied,—that is to say, placed on active military service within the confines of the United Kingdom. The occasion for issuing the proclamation must be first communicated by message to parliament if it be then in session; if it be not sitting, parliament must be called together within ten days. For the purpose of keeping the force in a condition of military efficiency, the officers and men are subjected to one preliminary training for a period not exceeding six (usually about two) months, and further to an annual training not exceeding fifty-six (usually twenty-eight) days. The force is composed of corps of artillery, engineers, and infantry. Infantry militiamen are formed into battalions constituting part of the territorial regiment of the locality of which the regular forces are the senior battalions. The officers and men when called out are liable to duty with the regulars and in all respects as regular soldiers within the United Kingdom. Of late years the men have been raised exclusively by voluntary enlistment, but where a sufficient number for any county or place is not thus raised a ballot may be resorted to in order to complete the quota fixed by the queen in council for that county or place. Each man is enlisted as a militiaman for the county, to serve in the territorial regiment or corps of the district. The period of engagement is not to exceed six years, but during the last of these years a militiaman may be re-engaged for a further period also not exceeding six years.

Men who illegally absent themselves are liable, in addition to punishment for the offence, to make up for the time of their absence by a corresponding extension of their service. The officers are appointed and promoted by the crown, but first appointments are given to persons recommended by the lord lieutenant of the county who may be approved as fulfilling the prescribed conditions in respect of age, physical fitness, and educational qualifications. Since 1877 the officers have been permanently subject to military law. The general body of the non-commissioned officers and men are so subject only when called out for training or embodiment. At other periods they have simply the legal status of civilians, except as regards a liability to trial and punishment for offences in connexion with enlistment or for military offences committed while called out. Each militia regiment has a permanent staff, consisting of an adjutant and a small body of non-commissioned officers and drummers, to conduct the recruiting drills and ordinary business of the corps; and the members of this permanent staff are always subject to military law. They mostly consist of non-commissioned officers who belong to or have served in the regular portion of the territorial regiment. Many of the militia corps have their headquarters at the brigade depôt or local establishment of the territorial regiment, and all are under the general supervision of the (regular) colonel commanding the brigade depôt. The area of service does not extend beyond the United Kingdom; but those who voluntarily offer to serve in the Channel Islands, the Isle of Man, Malta, or Gibraltar may be employed therein. The uniform of the officers and men of the militia is precisely the same as that of the regular corps with which they are associated, or rather of which they form part, except that in addition to the regimental distinguishing mark they bear the letter "M" upon their appointments, to denote that they belong to the militia portion of the corps.

As above stated, the ranks of the militia are usually filled by voluntary enlistment; but by a statute which, though temporarily suspended, can be put in force provisions are made for filling up any deficiency in the allotted quota in any county, city, or riding by ballot of the male inhabitants if within certain limits of age. The enactment provides as follows:—

The secretary of state is to declare the number of militiamen required, whereupon the lord lieutenant is to cause meetings to be held of the lieutenancy for each subdivision. To these meetings the householders of each parish are to send in lists of all male persons between the ages of eighteen and thirty dwelling in their respective houses. Before the ballot, however, the parish may supply volunteers to fill up the quota, every volunteer so provided and approved counting as if he were a balloted person. If a deficiency still exists, the persons on the lists shall be balloted for, and double the number of those required to supply the deficiency shall be drawn out. Any person whose name is so drawn may claim exemption or object; and the deputy lieutenants settle the question of his liability to serve. From the corrected list those who are of the requisite physique (the height is 5 feet 2) are enrolled in the order in which their names are numbered until the quota is completed. If the list is not sufficient to fill the quota, another ballot in the same manner is to be taken. Any balloted man becoming liable to serve may, however, provide a substitute who has the requisite physical qualifications, and is not himself liable to serve.

Within the general body of the militia is contained another having an additional and important obligation in the matter of service. It is called the "militia reserve," and is formed of men who voluntarily undertake a liability to join the regular forces and serve in any place to which they may be ordered in case of the proclamation of a state of imminent national danger or great emergency. In this respect they are in fact upon the same footing as the army reserve, and on the occasion of the mobilization of 1878 more than 20,000 of these men became part of the regular army. The present strength of the militia reserve is a little under 29,000 men, and judging by past experience it may be computed that about 25,000 could be at once added to the ranks of an army in the field in the event of national danger or emergency. It is to be observed, however, that every man thus added to the regulars would be taken away from the effective strength of the militia.

There is no statutory provision for the number of men to be maintained, that number being what from time to time may be voted by parliament. The latest information available respecting the actual condition of the militia of Great Britain relates to the year 1881, and that of Ireland to 1880, the militia of the latter country for obvious political reasons not having been called out for training in 1881 or 1882. Taking the militia of the United Kingdom in 1881, we find that the establishment provided for was 139,501, of whom 18,618 were artillery, 1317 engineers, and 119,566 infantry. Divided into ranks, this establishment was made up of 3534 sergeants and 1260 drummers of the permanent staff, and of the general body 3909 officers, 2520 sergeants, 5040 corporals, and 123,238 privates. The number actually enrolled was 127,868 of all ranks, leaving 11,633 wanting to complete. Of the number enrolled 84,864 belonged to English, 14,138 to Scotch, and 28,866 to Irish regiments, the numbers wanting to complete being for England 7420, for Scotland 162, and for Ireland 4051. As the Irish regiments were not called out, our information regarding the actual effective condition of the force as shown at the annual training does not include Ireland. With regard to the English regiments, 74,945 were present out of an enrolled strength of 84,864. Of the absentees 3144 were with and 6775 without leave. In the Scotch regiments, 12,401 appeared at the training, and of the absentees 616 were with leave and 1121 without. Of the total establishment (106,584) for Great Britain, 99,002 were enrolled, and of those enrolled 87,346 presented themselves and 3760 were absent with leave and 7896 actual defaulters. Of the English regiments five-sixths and of the Scotch regiments two-thirds were born in the county to which their regiments respectively belonged. Of 92,677 men (for Great Britain) whose occupations are disclosed, 17,665 were artisans, 22,221 mechanical labourers, 26,227 agricultural labourers, and 26,564 other trades. Speaking approximately, more than one-half of the men were between twenty and thirty years of age, about 4 per cent. between seventeen and eighteen, about 9 per cent. between eighteen and nineteen, and about 12 per cent. between nineteen and twenty, while some 20 per cent. were over thirty years of age. More than one-half those inspected in 1881 were between 5 feet 5 inches and 5 feet 7 inches in height, about 20 per cent. were under 5 feet 5 inches, while only 585 out of a total of 92,677 were 6 feet and upwards. At the date of inspection there were 296 men in military confinement and 465 in the custody of the civil power. On the last occasion (1880) on which the Irish militia were called out, upon an establishment of 32,813 and an enrolled strength of 30,515 the number present at the training was 26,399, leaving 706 absent with and 2264 without leave. Regiments numbering in the aggregate 1146 men were not trained.

As distinguished from the regular forces or standing army, the militia has been described as the constitutional military force of the country; and its history justifies the description, at least up to a recent period when it lost its distinctive character and became to a great extent merged in the regular army. It is the oldest force Britain possesses, and in fact represents the train bands of early English history. Its origin is to be found in the obligation of all freemen between certain ages to arm themselves for the preservation of the peace within their respective counties, and generally for the protection of the kingdom from invasion. This obligation, imposed in the first instance upon the individuals themselves, became shifted to the owners of land, who were compelled to keep up their proportion of horses and armour for the national defence. The forces were

placed under the lieutenant of the county, empowered in this respect by a commission from the crown. This prerogative of the sovereign, which had been in some instances a matter of controversy, was declared by statute shortly after the Restoration. By the same statute the militia of each county was placed under the lieutenant, who was vested with the appointment of officers, but with a reservation to the crown in the way of commissioning and dismissal. The cost of the annual training—for fourteen days—fell upon the local authority. Offences against discipline were dealt with by the civil magistrates, but with a power to the officers of fining and of imprisoning in default. Upon this footing the militia of England remained for nearly a century, with the general approval of the community. It was recognized as an instrument for defence and for the preservation of internal order, while it was especially popular from the circumstance that from its constitution and organization the crown could not use it as a means of violating the constitution or abridging the liberty of the subject. It was controlled and regulated in the county; it was officered by the landowners and their relatives, its ranks were filled by men not depending for their subsistence or advancement upon the favour of the crown; its numbers and maintenance were beyond the royal control; its government was by statute. While the supreme command was distinctly vested in the crown, every practical security was thus taken against its use by the crown for any object not constitutional or legitimate. It was regarded as, and was, in fact, the army of the state as distinguished from the standing army, which was very much the army of the king personally. The latter consisted of hired soldiers, and was more than once recruited by a conscription, confined, however, to persons of the vagrant class not having a lawful employment, while the former was mainly composed of those having a fixed abode and status. The militia thus enjoyed for many years as compared with the regular forces a social as well as a constitutional superiority. About the middle of the last century the militia was reconstituted, with certain modifications, not involving a sacrifice of the principle of its local government, but strengthening somewhat the supervising influence of the crown. Thus the king directly appointed the permanent staff, and was given a veto upon the appointment and promotion of the officers, who were to have a property qualification. A quota was fixed for each county, to be raised by ballot of those between the ages of eighteen and forty-five, each parish having the option of supplying volunteers at its own cost, and each man balloted being permitted in lieu of serving to pay £10 to provide a substitute. When called out for service the pay was to be the same as that of the regulars, and while embodied or assembled for annual training the officers and men were placed under the Mutiny Act and Articles of War, with, however, a proviso that in time of training no punishment was to extend to "life or limb." The crown was given the power to call out the militia in case of apprehended invasion or of rebellion, and associate it with the regular army, but only upon the condition of previously informing parliament if then sitting, and if it were not sitting of calling parliament together for the purpose. A further and important security was established to prevent an unconstitutional use of the militia by the crown: the estimate for its training was framed each year, not by an executive minister of the sovereign, but by the House of Commons itself. Upon the initiative of a committee of the House, an Act was passed providing for the pay and clothing of the militia for the year. Upon this footing substantially the militia of England remained for many years, the Irish and Scotch militias being meantime brought under the same conditions by various enactments. The force was embodied on several occasions during the last and in the early years of the present century, and it contributed largely to the army engaged in the Peninsula. From 1803 to 1813 just 100,000 men, or two-fifths of those raised for the army, came from the militia. In this way, however, it lost its distinctive character as a defensive force. During the peace which followed the final fall of Napoleon the militia was suffered to fall into decay; and up to 1852 it had only a nominal existence in the shape of an effete permanent staff with no duties to perform. In 1853 the militia was revived just in time to enable it to fulfil most valuable functions. In the war with Russia it was embodied and did garrison duty not only in the United Kingdom but in the Mediterranean garrisons, thus enabling the authorities to send most of the available regular troops to the scene of hostilities. It further contributed many officers and some 30,000 men to the line. It still gives annually about 8000 recruits to the regulars. During the Indian mutiny it filled scarcely less useful functions when again called out. It has since then been regularly assembled for annual training; and when it is brigaded with the regular forces at Aldershot and other camps of instruction its military aptitude and proficiency have generally elicited the surprised admiration of professional soldiers. In 1871 an important constitutional change was made. It was part of the new army system inaugurated in that year that the control of the militia should be removed from the lord lieutenant of the county and vested wholly in the crown. It has now virtually ceased to exist as a distinct body, and is a part of the regular forces with a limitation as to the time and area and other conditions of service. There is no longer a regiment of militia. The body that would formerly be thus described is now a collection of militiamen of a regiment largely composed of regulars. The votes for the maintenance of the militia are now part of the army estimates. The officers of the militia and the line are eligible for duty with either force, and may sit upon courts martial indiscriminately. This practical amalgamation of the old constitutional force with the standing army may appear theoretically open to the objection that it is thereby placed under the direct control of the sovereign. But the day has passed when such an objection could have any value. The fact of the whole army being placed in all respects under the direct control of a minister responsible not only to the crown but to parliament is enough to dissipate any constitutional apprehensions under this head.

The only colonial militia that forms an effective force is that of Canada, which is organized as an efficient local army. The Government of the Dominion includes a minister of militia and defence. The force is placed under the command of a general officer, assisted by an adjutant-general, belonging to the regular army and appointed by the queen. The training of the officers is a matter of special care, there being a military college at Kingston, several of the governing body and professors of which are officers of the Royal Artillery and Royal Engineers, as well as schools of gunnery and musketry. For military purposes the Dominion is mapped out in twelve districts. The militia is divided into the active and the reserve, and the male inhabitants between the ages of eighteen and sixty, with the usual exceptions, are liable to military service, the extent of which varies with the age of each man, the larger amount of duty falling upon the younger. The active militia comprises 12 regiments of cavalry, 17 field and 31 garrison batteries of artillery besides a mountain battery, 4 companies of engineers, 2 mounted rifle corps, 97 battalions of from 5 to 10 companies each and 16 independent companies of infantry. The uniform is for the most part like that of the regular army, and the organization and general efficiency of the whole body have been very favourably reported upon. Although the obligations of the Canadian militia are purely local, a large number on a late occasion offered themselves for general service; and, in the event of a war on a large scale, it is believed that the force would contribute a valuable addition to the fighting strength of the imperial army. (J. C. O'D.)

MILK is the fluid secreted by the mammary glands of the division of vertebrate animals called *Mammalia*. These glands are in a rudimentary form in the Monotremes. In *Ornithorhynchus* there is no nipple, but the mouth and tongue are closely applied over the area on which the ducts open, and the fluid is withdrawn by suction on the part of the young and compression of the gland by the mother. In *Echidna* the ducts of the gland open into a small pouch, foreshadowing the larger pouches of marsupials. In Marsupials the glands are more compact, and have a greater number of lobules. They are found behind the marsupial depressions or those of the pouch; they are not fewer than two on each side nor more than thirteen, six on each side and one midway. The ducts, long and slender during lactation, open on a nipple which is covered by a reflexion of the skin at the back of the pouch, thus forming a kind of hood or sheath. The nipple is protruded beyond the hood during lactation, and is much elongated. The number of these nipples bears a relation to the number of young at a birth; thus the kangaroo, with one at a birth, has four nipples (two, generally the anterior pair, being in use), whilst the Virginian opossum, which produces six or more at a birth, has thirteen nipples. Rodents show a corresponding provision for the nourishment of the young in the number of nipples. A seeming exception is the common guinea-pig, which frequently has eight, ten, or twelve young at intervals of two or three months, and yet the mother has only two teats to serve them, turn and turn about; the original stock of the domestic species breeds, however, only once annually, and has but one to two young, so the domestic variety is a curious anomaly due to the artificial circumstances of its life. In the porcupines there are two nipples, one midway between the fore and hind leg, and the other midway between this and the base of the fore leg. In the coypu, a creature often carrying its young on its back whilst it swims across rivers, the teats project from the flanks near the shoulders, and are of considerable length,

so that the young readily reach them. The *Insectivora* have, as a rule, more nipples than are found in any other order. Thus in the tenrec (*Centetes*) there are as many as twenty-two, and they are rarely fewer than fourteen, spread out in pairs from the pectoral to the inguinal regions. There are ten teats in the common hedgehog, six to eight in moles and shrews, two in sloths and armadillos. In *Cetacea* there are two long, narrow, flat glands lying between the dermal and abdominal muscles, with the subcutaneous blubber separating them from the skin. The peculiarity of the arrangement in these animals, where suckling is performed under water, is the large size of the central duct, which acts as a kind of reservoir, so that the young may obtain a considerable supply in a very short time. It would appear also that when suckling takes place the nose of the young is above the surface of the water. Among Ungulates, in the elephant the glands and teats are between the fore legs; in the rhinoceros they are inguinal; in the mare and ass the glands are two in number, and are found between the thighs, about 9 inches in front of the vulva; the tapir has two inguinal nipples, the peccary two ventral and two inguinal, the wild sow eight nipples, whilst in the domestic breeds there are at least ten, extending from the pectoral to the inguinal regions. Ruminants have the glands aggregated into a round mass in the inguinal region, pendulous in full function, divisible into two glands, each of which has a large reservoir. When in use the teats, one pair or two pairs being the number, in connexion with the reservoirs become so large as to receive the special name of "udder." All the deer tribe, camels, the giraffe, and all kinds of cows have four teats; most antelopes and the gazelles have two teats, whilst a few antelopes have four. As to *Carnivora*, the felines have usually six nipples; the wolf, jackal, fox, dog have usually eight; the seals and the walrus have four, the otters two, the weasels six, the bears six; and in the kinkajou (*Cercoleptes*) the number is reduced to two. Amongst *Quadrumana*, the aye-aye (*Chiromys*) has only one pair of nipples, about an inch and a half in front of the vulva; many lemurs have in addition to those a pectoral pair; in all the platyrhine and catarhine *Quadrumana* there is only one pair of glands, restricted to the pectoral region. Here the teats are between the fore legs, and the young clings to the mother's breast in human fashion, but there is no protrusion of the breast as in the human being. (For further details see Owen's *Anatomy of Vertebrates*, vol. iii. p. 769.)

In the human race the glands are two in number, forming, along with the skin and fat, two rounded eminences, one on each side, on the front of the thorax. They extend from the third to the sixth or seventh rib, and from the side of the sternum to the axilla. In the centre projects a small conical body, the *nipple*. Around the nipple is a coloured circle, or *areola*, which is darker during pregnancy, and even in women who have borne children than in the virgin state. The surface of the nipple is wrinkled, and with a magnifying glass is seen to be covered with papillæ. It is perforated by numerous openings, the mouths of the milk ducts. The tissue of the nipple contains numerous minute blood-vessels, and it has at the base muscular fibres arranged in concentric circles and in radiating bands. It has much of the character of erectile tissue, as in the *corpora cavernosa* of the penis, becoming turgid, firm, and prominent from excitement. The base of the gland lies on the pectoral muscle, a thin layer of fascia intervening. The surface is covered with fat, which gives it the smooth rounded outline. It is amply supplied with blood by the long thoracic artery, some other minute branches of the axillary artery, the internal intercostal artery, and the subjacent intercostals. The nerves come from the anterior and middle intercostal cutaneous branches, and the nipple is especially sensitive. The gland is composed of numerous lobes bound together by connective and adipose tissue, and each lobe is formed of smaller lobules. Each lobe has an excretory duct, and these ducts, from fifteen to twenty in number, converge towards the areola, beneath which they are dilated so as to form sinuses from $\frac{1}{6}$th to $\frac{1}{4}$th of an inch in calibre. From these sinuses arise the ducts which open on the surface of the nipple. The general structure will be understood by referring to the accompanying figures, along with the description.

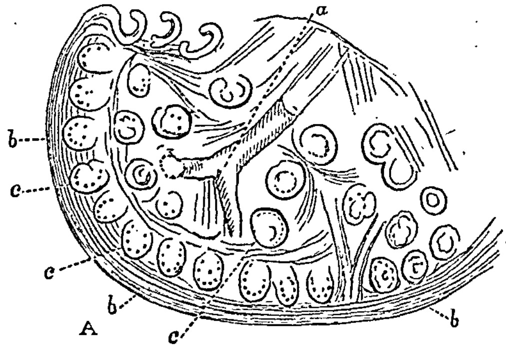


FIG. 1.—Half-diagrammatic view of a section through a lobule of the mammary gland, after Klein (*Atlas of Histology*, plate xl. fig. 1), magnified 45 diameters. *a*, a duct dividing into two branches; *b, b, b*, connective tissue surrounding and going between the ultimate pouches of the gland; *c, c, c*, the pouches or *alveoli* of the gland, the dots representing the cells lining them.

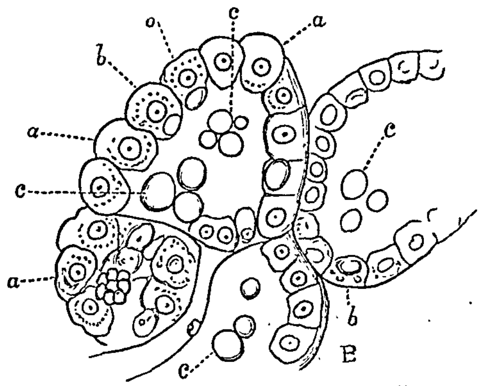


FIG. 2.—A portion of the same gland, magnified about 400 diameters, showing one complete and two incomplete alveoli. *a, a, a*, short, columnar, epithelial cells lining the alveolus, each having an oval or rounded nucleus; *b, b, b*, epithelium cells, containing, next the interior of the alveolus, a milk globule; *c, c, c, c*, milk globules which have been set free from epithelial cells.

When a duct is traced into the gland, it is found to subdivide into smaller ducts, and these into still smaller, until the smallest ductlet is reached, round the end of which are clustered several *alveoli* or pouches. Each alveolus has a wall, lined with epithelium cells. In the wall of the alveolus there are capillary blood-vessels which bring the blood near the cells. By this blood the cells are nourished. There is a minute cavity in the centre of each alveolus into which cells or their products can accumulate. There can be no doubt that the formation of the milk globule takes place in these cells. Whilst milk is not being formed the cells have a granular appearance, and the lumen or central cavity of the alveolus is small; but during secretion the cavity is enlarged and shows a few milk globules, whilst one or more milk globules can be seen in the interior of the cell. If the milk globule in the cell be very large, the nucleus of the cell is pressed outwards and the protoplasm of the cell is reduced to a thin covering, over the globule, at this stage presenting a striking resemblance to a fat cell containing an oil globule. Thus each milk globule is formed in the protoplasm of the epithelium cell, and even at an early stage each milk globule consists of a minute drop of fat or oil surrounded by a thin albuminous envelope. It has not been clearly ascertained whether epithelial cells, after having secreted milk globules, degenerate and fall off, or whether they have the power of ejecting the milk globules. The fluid constituents of milk (water holding

salts in solution) may be separated from the blood by a kind of filtration under blood pressure, as is the case in other secretory processes. The origin of the sugar of milk and of the casein is unknown. (For a description of the minute structure of the milk gland, see Klein's *Atlas of Histology*, p. 300, and references.) At the beginning of lactation the milk is rich in large irregularly-formed corpuscles (fig. 3, *a*, *a*, *a*) called *colostrum* corpuscles. These are contractile bodies, slowly changing their form and squeezing out the oily particles. At first they are the only bodies present, but they are soon replaced by the ordinary milk globules. Such globules have bright refractive edges, the surface is smooth, they vary in size from $\frac{1}{8000}$th to $\frac{1}{3000}$th of an inch in diameter, and each consists of a drop of fatty matter surrounded by a layer of albumen ("Ascherson's membrane").

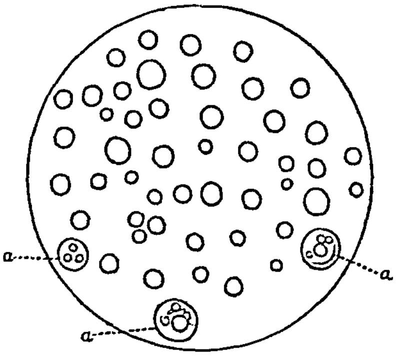


FIG. 3.—A drop of milk magnified 300 diameters. *a*, *a*, *a*, *colostrum* corpuscles.

A secretion of milk takes place in newly-born children, from the fourth to the eighth day, and also in rare cases in men (Hermann's *Physiology*, p. 158). During gestation in the human being the mammary glands increase in size; immediately after the birth of the child active secretion commences; and usually it is on the stoppage of the secretion, ten months afterwards, that the process of menstruation, which has been arrested by impregnation, again is re-established.

The secretion of milk is undoubtedly affected by the nervous system, as is shown by fear or mental distress arresting or injuring the quality of the secretion, and by the "rush" or feeling of fulness in the breast experienced by the mother when the child's mouth touches the nipple, or even when she sees her offspring. The nervous mechanism, however, is unknown, as it has been observed that secretion may continue even after section of all the nerves known to pass to the gland. The nature of the diet has a marked influence on the quality of the secretion. Thus the amount of casein and of fat is greater during an animal than during a vegetable diet. Fatty foods do not seem to increase the amount of fat or butter; an ample supply of carbo-hydrates (starches and sugars) increases the amount of sugar. These facts indicate that most if not all of the constituents of milk are formed from changes in the protoplasm of the epithelial cells. In some women the milk is deficient in fat and casein, and consequently is less nutritious. Prolonged lactation diminishes the amount of fat and sugar without materially affecting the amount of albuminous matter; but the milk is less nutritious and is unfit for the child. The occurrence of menstruation during lactation also deteriorates the milk. (J. G. M.)

Milk as Food.

The milk of various domesticated animals is more or less used by man for food. The milk of the cow, which may be taken as typical of all others, and is indeed by far the most important and valuable of all, is, when newly drawn, an opaque white fluid, with a yellowish tinge, soft, bland, and sweetish to the taste, and possessed of a faintly animal odour. This odour, according to Schreiner, is due to the presence of sulphuretted hydrogen, and disappears after a short exposure. The specific gravity of milk ordinarily ranges from 1·029 to 1·033, very seldom reaching 1·035 or falling so low as 1·027. In chemical constitution it consists of an emulsion of fatty globules (cream) in a watery alkaline solution of casein, and a variety of sugar, peculiar to milk, called lactose. The fat (which when separated we know as butter) and the lactose constitute the carbonaceous portion of the milk regarded as food. The casein, which forms the principal constituent of cheese, and a certain proportion of albumen which is present, form the nitrogenous, while the complex saline substances and water are the mineral constituents. These various substances are present in the proportions which render milk a perfect and typical food suitable to the wants of the young of the various animals for whom it is provided by nature. The milk of all animals, so far as is known, contains them, although they are present in somewhat different proportions. It is probable that the milk of ruminants possesses certain physical and physiological distinctions from that of non-ruminant animals, which will account for the virtues attributed to the milk of the ass and mare. The following table exhibits the chemical constitution of the kinds of milk most frequently used by man:—

	Cow.		Goat.	Ewe.[1]	Mare.	Ass.	Human.
	Winter Blyth.	Cameron.	Voelcker.	Voelcker.	Cameron.	Chevallier and Henry.	Gerber.
Water	86·87	87·00	84·48	83·70	90·310	91·65	88·02
Fat	3·50	4·00	6·11	4·45	1·055	0·11	2·90
Casein and albumin	4·75	4·10	3·94	5·16	1·953	1·82	1·60
Sugar	4·00	4·28	4·68	5·73	6·285	6·08	7·03
Ash	0·70	0·62	0·79	0·96	0·369	0·34	0·31

In addition to these constituents milk contains small proportions of the gases carbonic acid, sulphuretted hydrogen, nitrogen, and oxygen, and minute quantities of other principles, the constant presence and essential conditions of which have not been determined. These consist of galactin and lactochrome, substances peculiar to milk, discovered by Winter Blyth, with certain animal principles such as leucin, pepton, kreatin, tyrosin, &c. The salts in milk consist, according to the average of numerous analyses by Fleischmann, of the following constituents:—

Phosphoric acid	28·31	Potash	17·34
Chlorine	16·34	Magnesia	4·07
Lime	27·00	Ferric oxide	0·62
Soda	10·00		

Milk thus is not to be regarded as a definite chemical compound nor even as a mixture of bodies in fixed and invariable proportions. Not only does the milk of different races and breeds of cows vary within comparatively wide limits; the milk of the same animal is subject to extensive fluctuation. The principal causes of variation in the individual are age, period of lactation, nature and amount of food, state of health, and treatment, such as frequency of milking, &c. The following table indicates the range of normal variations:—

Water	90·00	to	83·65
Fat	2·80	,,	4·50
Casein and albumin	3·30	,,	5·55
Sugar	3·00	,,	5·50
Ash	0·70	,,	0·80

The average quantity of milk yielded by cows is also highly variable, both in individuals and breeds. As a rule the smaller breeds of cows yield a small amount of milk rich in cream (butter fat), while the yield of the larger breed is greater in quantity, but comparatively deficient in cream. A good milch cow should yield in a milk-giving period of from eight to nine months about

[1] Ewe's milk is exceedingly variable, especially in its percentage of fat. The above analysis is one of nine by Dr Voelcker, in which the fat was found to range from about 2 to 12¾ per cent.

500 gallons of milk, from which nearly 500 ℔ of cheese or 200 ℔ of butter would be obtainable.

Dairy Treatment.—Cows are commonly milked by hand two or three times a day. A milking machine of American origin, which was introduced about the year 1862, has been entirely abandoned. The milk should be drawn from the animals in as clean a condition as possible, but notwithstanding every precaution some amount of hair and epithelial and other animal débris invariably enters the milk-pail. It has therefore to be immediately strained through a sieve with fine wire-cloth or hair strainer. As milk is peculiarly susceptible of taint, and absorbs odours of all kinds with great avidity, it is of the utmost consequence that all vessels in which it is placed or kept should be so made as to be easily purified and that they should be kept scrupulously clean. In Switzerland milk is strained with most beneficial effect through sprigs of washed fir tops, which inserted loosely and uprightly into the hole of a funnel arrest all hair, skin, clots, and slimy matter on the acicular leaves. The milk drains through in a clean condition with a fresh slightly aromatized flavour favourable to its keeping. A fresh sprig is used on each occasion of straining milk, so that there is freedom from the risk of taint which arises through the use of imperfectly cleaned wire gauze. The milk must be removed from the cow-house as quickly as possible; and, if intended for use as new milk and for sale in the neighbourhood of the dairy, it may at once be put up for delivery. But if it has to travel a distance, or if it is to be kept for creaming or cheese-making, it should be rapidly cooled down, and kept in a cool airy milk-room if practicable, surrounded with fresh cold water.

The ordinary method of separating cream either for direct use or for butter making is by allowing it to form on the surface and skimming it off with a broad flat spoon; but ingenious adaptations of centrifugal machines—of which Laval's separator is one of the best known—have been introduced for the purpose of effecting the rapid and complete separation of the cream. The centrifugal force of such machines throws the denser portions of the fluid towards the sides of a rapidly revolving cylinder, collecting the cream on an inner layer, which is carried off by one channel while the impoverished milk escapes by another. The Laval separator gives very rich cream, as will be seen from the following analyses by Voelcker:—

	Ordinary Cream.	Cream by Separator.	Skimmed Milk by Laval Separator.	Ordinary Skimmed Milk.
Water	77·30	66·12	90·82	89·25
Butter fat	15·45	27·69	0·31	1·12
Casein	3·40	2·69	3·31	3·69
Milk sugar	3·15	3·03	4·77	5·16
Mineral matter	0·70	0·47	0·79	0·78

After being kept some time, depending principally on the temperature at which it is maintained, milk begins to turn sour owing to the formation of lactic acid, by a process of fermentation, at the expense of the lactose or milk sugar. The acid so developed causes a coagulation of the casein, and the milk separates into a solid white curd, and a thin transparent yellow milk serum or whey. These changes can to a certain extent be artificially produced, hindered, and controlled. The following are the results of analyses by Fleischmann:—

Constituents of 100 Parts of Sweet Milk.

20·00 cream	3·56 butter. 16·30 buttermilk. 0·14 loss.
79·70 skimmed milk	7·93 curd. 71·45 whey. 0·32 loss.
0·30 loss	0·30 loss.

Relative Composition of Milk and its Products.

	Water.	Fat.	Casein.	Albumin.	Milk Sugar.	Ash.
Whole milk	87·60	3·98	3·02	0·40	4·30	0·70
Cream	77·30	15·45	3·20	0·20	3·15	0·70
Skim-milk	90·34	1·00	2·87	0·45	4·63	0·71
Butter	14·89	82·02	1·97	0·28	0·28	0·56
Buttermilk	91·00	0·80	3·50	0·20	3·80	0·70
Curd	59·30	6·43	24·22	3·53	5·01	1·51
Whey	94·00	0·35	0·40	0·40	4·55	0·60

The simplest and most advantageous form in which milk can be disposed of as a commercial product is by its sale as sweet or new milk, and it is in this manner that the greater proportion of the milk produced within the reach of large centres of population is disposed of. New milk, cream, and skimmed milk are the only primary forms in which milk is sent into the market. CHEESE and BUTTER have been dealt with in separate articles (*q.v.*). Whey, the yellow liquid remaining after the separation of the curd in cheese making, is a source of milk sugar, employed to a limited extent in pharmacy; but it is principally used for feeding pigs. The buttermilk which remains after separating butter is a most wholesome and nutritious article of food.

Preservation of Milk.—The numerous methods which have been proposed for the preservation of milk in a condition fit for use over a lengthened period resolve themselves into (1) chemical treatment with alkaline salts and antiseptic bodies, (2) physical treatment, such as cooling or icing, boiling, and aeration, and (3) condensation with or without the addition of a preservative agent. All systems of preservation, however, are subject to serious disadvantages either from their serving their purpose for too limited a time, or their interfering with the natural constitution and properties of the milk. Of all preservatives cold is the most efficient and least objectionable. It has been shown by Soxhlet (*Dingler's Polytech. Journal*, ccxxiii. 329) that milk cooled by ice-water remains sweet and unaltered for fourteen days, but after that time acquires a rancid taste. After twenty-eight days it coagulates on boiling owing to the presence of acids resulting from the oxidation of the cream, and in thirty-four days it coagulates even in the ice-water. It is also found that milk which has undergone aeration with atmospheric air has its keeping properties much improved. The aeration is effected by allowing the milk to fall from some height in a state of fine division by passing it through the meshes of a sieve. By another method air cooled by passing over ice is blown through the milk.

Milk keeps sweet for a longer time when boiled, but the smell, taste, and other properties are affected, partly owing to the escape of gases mixed with it when fresh. The unpleasant flavour communicated by boiling can be avoided if the action takes place in a closed vessel and the milk is immediately cooled down in a refrigerator connected therewith. In the case of any suspicion of taint in milk either from disease in the cow, contamination from unhealthy persons, or the use of infected water in cleaning vessels, boiling is also strongly to be recommended, as it effectually destroys the germs of disease, in the carrying and spreading of which milk is a most active agent. It is with the utmost difficulty that boiled milk can be coagulated by means of rennet; but by treatment with acid it coagulates more rapidly and freely than if unboiled.

Of the various chemical compounds which have been suggested and more or less used for preserving milk, the most successful hitherto has been salicylic acid, which has the advantage of being tasteless and inodorous. By briskly stirring in rather less than 2 grains to a pint of milk, it can be kept liquid and sweet in a temperature of from 65° to 68° Fahr. for twelve hours, and at 55° Fahr. for a whole day. If 4 grains be used to a pint, coagulation in the higher temperature is delayed from two or three days, and at the lower temperature the milk may be kept good from three to five days. Boracic acid and borax are also employed by dairymen, the former being known as glacialine salt. The presence of any chemical antiseptic in milk is, however, at best a matter of doubtful advantage.

Condensation.—Milk is now treated on a large scale by a process of concentration, the product of which comes into the market in two forms—as "plain condensed milk" and as "preserved milk." The credit of originating the industry is due to Mr Gail Borden of White Plains, New York, who began his experiments about 1849. In 1851 he introduced his plain condensed milk, which is simply milk from which between three-fourths and four-fifths of the water has been removed, and in 1861 he rendered important services to the army in the field by supplying preserved milk which was in

effect milk similarly concentrated, with a proportion of sugar added, and hermetically sealed in tin cans. The manufacture was transplanted to Switzerland in 1865, after which condensing factories were established in England, Ireland, Denmark, Bavaria, Norway, and elsewhere. With the introduction of the condensing trade there has also been associated the factory system of dealing with dairy products, by which the milk of many dairies is carried to one centre and dealt with either for condensing or for cheese or butter making. The following epitome of the process of condensing milk is from a paper by Mr Willard of Cornell university, New York (*Jour. Roy. Agric. Soc.*, 2d series, vol. viii., 1872). The milk when received at the factory is first passed, he says, "through a strainer to the receiving vat; from this it is conducted off, going through another strainer into the heating cans, each holding about 20 gallons; these cans are set in hot water, and the milk is held in them till it reaches a temperature of 150° to 175° Fahr.; it then goes through another strainer into a large vat, at the bottom of which is a coil of copper pipe, through which steam is conducted, and here the milk is heated up to the boiling point. Then the best quality of white granulated sugar is added, in the proportion of 1¼ lb of sugar to the gallon of milk, when it is drawn into the vacuum-pan having a capacity of condensing 3000 quarts or more at a time. The milk remains in the vacuum-pan subjected to steam for about three hours, during which time about 75 per cent. of its bulk in water is removed, when it is drawn off into cans, holding 40 quarts each. The cans are only partially filled, and are then set in a large vat containing cold water, the water being of a height equal to that of the milk in the cans. Here it is stirred until the temperature of the condensed fluid is reduced to a little below 70°; it is then turned into large drawing-cans with faucets, in order to facilitate the filling of the small cans, ... holding 1 lb each, which are immediately soldered to exclude the air."

In the case of plain condensed milk the concentration is usually carried farther than is practised in preparing the preserved milk, it being evaporated down to between one-fourth and one-fifth of the original bulk. It is not put up in sealed tins, being intended for immediate use, and keeps sweet only for a few days, varying with the state of the weather, whereas the sugared milk in sealed cans keeps for years. The large amount, however, of cane sugar added to preserved milk seriously disturbs its balance of proportion as a perfect food, and renders it unfit to be used alone in a dilute state as a substitute for mother's milk by infants, a purpose for which it is largely employed. It should also be observed that the relative proportion of fat is small, the milk being partially skimmed before it is operated on, so that the statement that preserved milk diluted with a small proportion of water is equal to cream is not to be relied on. Preserved milk, rich in cream, has always a more or less rancid oily taste, and cannot be obtained so sweet and even in flavour as that largely deprived of fat. According to a German patent of E. Klebs in Prague, plain condensed milk may be preserved by adding to every 100 litres of the original milk a solution of 50 grains of benzoate of magnesium in one litre of water.

Adulteration.—Practically the invariable mode of sophisticating milk for sale consists in the addition of water and in the subtraction of cream,—in other words, passing off skimmed or partly skimmed as new milk. Now and again there are found certain little refinements on these simple frauds, such as adding a quantity of sugar to correct the specific gravity, flour or starch to increase opacity, and a touch of colouring matter to cover the bluish tinge which would betray skimmed milk. In the United Kingdom no official standard of what constitutes pure milk has been promulgated, but the so-called Somerset House standard has been generally recognized in law courts. According to this, new milk should contain as a minimum of solids not fat 8·6 per cent. and of fat 2·5 per cent., and of water a maximum of 88·9 per cent. The most satisfactory manner of discovering the probable genuineness of a sample of milk is by chemical analysis carried sufficiently far to determine the amount of fat and of other solids present. Numerous attempts have been made to place in the hands of dairymen, dealers, and consumers of milk a trustworthy method of estimating the condition and value of the article by simple quantitive tests for cream or fat—at once the most valuable constituent and one the presence of which in average proportion is indicative of the quality of the whole. The simplest but at the same time the least trustworthy and efficient method is by means of the so-called "creamometer," which consists merely of a graduated glass tube in which a measured amount of milk is placed and the amount of cream it throws up is read off by means of the scale. Specific gravity determinations have by themselves no significance, seeing milk deprived of its cream can by dilution with water be brought to correspond exactly with the original milk. But by a combination of two methods,—first taking the specific gravity, next observing the yield of cream by the "creamometer," and finally taking the specific gravity of the milk deprived of cream, regard being had to the temperature of the milk in these observations, an approximately accurate idea of the value of a sample may be obtained. Among so-called "lactoscopes," the operations of which are based on the fact that milk rich in cream is a much more opaque fluid than that from which cream has been taken or to which water is added, that invented by Professor Feser of Munich is one of the simplest and most useful. It consists of a glass tube open at the upper end and attenuated at its lower extremity. Into this narrower portion is fused a small cylindrical rod of opaque milk glass on which black lines are marked. These lines are invisible when the lower portion of the tube is filled with a measured quantity of milk, but on addition of water they become visible. When the black lines become by the gradual admixture of water perfectly distinct, the richness of the milk in cream globules is indicated by the height to which the mixture of milk and water has risen in the wide portion of the tube, which has engraved on it a scale showing on one side the amount of water added and on the other the proportion of cream equivalent to the transparency resulting from such addition.

Statistics.—In the year 1878 it was calculated by Mr J. C. Morton that the total yield of milk from the 2,250,000 cows and heifers in milk or in calf in England and Scotland amounted to about 1,000,000,000 gallons yearly. He assumed that about one-sixth of that quantity (167,000,000 gallons) went to feed calves, and that the daily consumption of the population was 1,000,000 gallons, being rather more than a quarter of a pint per head, which accounts for 365,000,000, still leaving 468,000,000 gallons to be used for butter and cheese making. Two-thirds of this quantity, or 312,000,000 gallons, Mr Morton assumes was used for cheese-making, yielding 2,800,000 cwts. of cheese (rather less than 1 lb per gallon of milk), and the remainder, 156,000,000 gallons, of milk devoted to butter-making would yield 530,000 lb of butter, or 1 lb of butter for every 21 pints of milk. In these figures no account is taken of Ireland, whence at that period there were sent to England alone yearly 3,500,000 lb of salted butter. In June 1882 the number of cows and heifers in milk and in calf in Great Britain did not vary greatly from the number on which Mr Morton's estimate for 1878 was based, being 2,267,175, whilst in Ireland the number was 1,398,965, making the total for the United Kingdom 3,682,317. If we take approximately Mr Morton's data as the basis of calculation, the 3,682,317 milk cows and heifers in the United Kingdom would yield, at 440 gallons per head, 1,620,219,480 gallons of milk. Further, assuming that one-sixth of this is consumed by calves, one-third consumed by population, one-third used for cheese-making, and one-sixth used for butter-making, we have as the yield of cheese 4,846,000 cwts. and as the yield of butter 920,000 cwts. As Ireland is much more a butter-producing than a cheese-yielding country, the quantity of cheese made is probably overestimated in these figures, and the amount of butter made is correspondingly understated. To bring out the consumption of dairy products for the year the following imports must be added:—

	Cwts.	Value.
Cheese	1,692,495	£4,742,368
Butter (including butterine)	2,167,428	11,339,226

Thus we find the total supply of cheese to the United Kingdom in 1882 was 6,538,495 cwts., and of butter the supply was 3,087,428 cwts. Estimating the home produce of both articles at the same value as the imports, the cheese supply cost £18,320,000, and the butter £16,150,000. Adding to these the probable cost of the milk consumed as such (say 550,000,000 gallons at 1s. per gallon =£27,500,000), we have for the year 1882 in round numbers £62,000,000 expended on dairy produce within the United Kingdom.

The total number of milch cows at present (1883) in the United States is stated at 15,000,000, which, taking the 440 gallons basis, yield annually 6,600,000,000 gallons, or nearly 30,000,000 tons of milk. In America the factory system of treating milk has attained much greater dimensions than in Europe, and that perfection of treatment, combined with the cheapness of raising and feeding stock, enables the American companies to enter the European markets with large quantities of cheese and other dairy products of uniformly good quality which find a ready and remunerative sale.

Koumiss.—Under this name is properly understood a fermented drink prepared from mare's milk by the Tartar tribes of the Russian empire and by all the nomad races of the northern parts of Asia. It is made by diluting mare's milk with about one-sixth part of its quantity of water, and adding as a ferment about one-eighth part of very sour milk or of old koumiss. This mixture is placed in a wooden vessel which is covered over with a thick cloth, and so left for about twenty-four hours in a moderately warm situation. During that time a thick coagulum rises to the surface, which is thoroughly reincorporated by churning. After standing for another day, the whole mass is again thoroughly churned and mixed up, and in this state it forms new koumiss, having an agreeable subacid taste. The liquor is mostly stored and preserved by the Tartars in skin bottles, in which the fermentation continues developing its alcoholic qualities, and mellowing and improving its taste. Genuine Tartar koumiss has the following composition:—alcohol 3·21, lactic

acid 0·19, sugar 2·10, albuminoids 1·86, fat 1·78, salts 0·509, carbonic acid 0·177, and water 93·46. A distilled spirit is prepared from koumiss, which is drunk among the Tartars under the name of araca or arsa. Koumiss has of late years come into prominent notice as a remedial agent in cases of pulmonary consumption, and generally as a nutritious form of food easily assimilated by delicate stomachs. It is probable that all its virtues reside in the original milk from which it is prepared, in which case the koumiss can only be regarded as valuable in so far that it is a convenient form under which the essential properties of the milk can be preserved for use. Under the name of koumiss a preparation of cow's milk is now very generally sold. It is made by adding to each quart of new milk about a tablespoonful of common sugar and brewer's yeast, allowing the fermentation to proceed a sufficient length, then bottling and corking as in the case of aerated waters. Such a preparation contains about the same proportion of alcohol as genuine koumiss, but a non-alcoholic variety can also be obtained, made by a process of natural fermentation, which continuing after bottling develops a large amount of carbonic acid and renders the liquor highly effervescent. (J. PA.)

MILL, JAMES (1773–1836), historian and political and mental philosopher, was born 6th April 1773, in the little village called Northwater Bridge (Bridge of North Esk), in the parish of Logie-Pert, in the county of Forfar. His father, James Mill, was a shoemaker; his mother, Isabel Fenton, belonged to a race of respectable farmers. The father was industrious, good-natured, and pious, but not known as specially intelligent. The mother was of a proud disposition, and resolved to educate James, her eldest son, for a superior destiny. He began his education at the parish school, and went on to the Montrose Academy, where he remained till the unusual age of seventeen and a half, when he went to the college of Edinburgh (1790). According to the usage of the time and neighbourhood, he ought to have been sent about thirteen or fourteen to Marischal College, Aberdeen. His remaining so long at the Montrose Academy, and his going to Edinburgh for his university course, must be connected with his being taken up by Sir John and Lady Jane Stuart of Fettercairn, who engaged him to be tutor to their only daughter, known for having inspired the affection of Sir Walter Scott, and for being the mother of Principal James David Forbes. Sir John and Lady Jane Stuart contracted a warm attachment for Mill, which lasted throughout their lives. At Edinburgh University Mill was distinguished as a Greek scholar. But he received his greatest impulse from Dugald Stewart, for whom he always expressed unbounded admiration. In October 1798 he was licensed as a preacher, but seems to have preached very seldom. His years from 1790 to 1802, besides being occupied with incessant studies extending into history and moral and political philosophy, were devoted to various tutorships.

Failing to find a career to his mind in Scotland, in 1802 he went to London in company with Sir John Stuart, then member of parliament for Kincardineshire. He soon obtained literary occupation, to which he applied himself with untiring energy. His first important venture was to start a periodical on a new plan, entitled *The Literary Journal*, which began to appear in January 1803, and continued under his editorship till the end of 1806. It was the most comprehensive in its aims of any periodical hitherto in existence, being a summary view of all the leading departments of human knowledge. Thomas Thomson, the chemist, took charge of science; and many other men of ability co-operated. Mill himself wrote largely in biography, history, political philosophy, political economy, and also in theology, on which his views at the time were broad without being sceptical. The publisher of the journal was Baldwin, who was also the proprietor of the *St James's Chronicle*, a Conservative paper appearing three times a week. For two or three years, from 1805 onwards, Mill was editor, but at last gave it up, partly on conscientious grounds, although in conducting it he never lent himself to the expression of any illiberal views, but often made it the vehicle of the opposite.

In 1804 he wrote a pamphlet on the *Corn Trade*, advocating the impolicy of a bounty on the exportation of grain. This was the beginning of his career as a political economist. In 1805 he published a translation of Villers's work on the *Reformation*, an unsparing exposure of the vices of the papal system. He added notes and quotations by way of confirmation of the author's views. On this subject also he continued to hold strong opinions all through life, and often recurred to it in his articles in the reviews. In 1805 he married Harriet Burrow, whose mother, a widow, kept an establishment for lunatics in Hoxton. He then took a house in Rodney Street, Pentonville, where his eldest son, John Stuart, was born in 1806. It was about the end of 1806 that he entered upon the composition of the *History of India*, which he expected to finish in three or four years. He was actually engaged upon it for twelve, giving, however, a considerable portion of his time to other writing for the support of his family. The strain upon his energies for those years was enormous.

He became acquainted with Jeremy Bentham in 1808, and was for many years Bentham's chief companion and ally. In 1810 Bentham, to have Mill nearer him, gave him Milton's house, which adjoined his own, and was his property. After a few months' trial Mill had to give up this house on account of his wife's health, and went to live in Newington Green; but in 1814 Bentham leased the house No. 1 Queen's Square, now 40 Queen Anne's Gate, close to his own garden, and gave it to Mill at a reduced rent; here he remained till 1831. The intimacy with Bentham was rendered still closer. For four years, from 1814 to 1817, Bentham was at Ford Abbey, near Chard, in Somersetshire, and there Mill and his family were domesticated with him nine or ten months each year,—in which retirement it is probable that Mill was able to accelerate the completion of his history.

In the twelve years between 1806 and 1818 he wrote a great many articles for various periodicals. Among these were the *Anti-Jacobin Review*, the *British Review*, and the *Eclectic Review*; but there is no means of tracing his contributions. In 1808 he began to write for the *Edinburgh Review*, and contributed steadily till 1813, most of his articles being known. In the *Annual Review* for 1808 two articles of his are traced—a "Review of Fox's History," and an article on "Bentham's Law Reforms," probably his first published notice of Bentham. The first known article in the *Edinburgh* was on "Money and Exchange" (October 1808). In 1809 (January and July) he wrote at great length on Spanish America and General Miranda, with whom he was on terms of intimate friendship. In the July number he also wrote on China. In 1810 (April) he made a severe attack on the East India Company. He also wrote on the liberty of the press and on the Church of England in connexion with the Lancasterian schools. He was an active member of the committee for promoting education on Lancaster's plan. In 1811 a periodical named the *Philanthropist* was started by William Allen, and published in quarterly numbers till 1817. Mill co-operated with Allen both in the writing and in the management. He contributed largely to every number,—his principal topics being education, freedom of the press, and prison discipline (under which he expounded Bentham's "Panopticon"). He made powerful onslaughts on the church in connexion with the Bell and Lancaster controversy. In 1814 Macvey Napier engaged him to contribute to the supplement to the fifth edition of the *Encyclopædia Britannica*. Many of the articles became notable. The list included "Government," "Jurisprudence," "Liberty of the Press," "Prisons and Prison Discipline," "Colony,"

"Law of Nations," "Education," "Beggar," "Benefit Societies," "Banks for Savings." In "Jurisprudence" and "Prisons" he was largely indebted to Bentham; in most of the others he was either altogether or in great part original. The article on "Government" will occupy a permanent position in English history.

In 1818 was published the *History of India*, which had a great and speedy success. It was the means of changing the author's future position. The year following he was appointed an official in the India House, in the important department of the examiner of Indian correspondence. He gradually rose in rank till he was appointed, in 1830, head of the office. He introduced his eldest son into the same department in 1823.

In 1824 Bentham projected the *Westminster Review*, and Mill was a principal writer for three years. Some of his most vigorous writings are included among those contributions. The first was an elaborate criticism of the *Edinburgh Review* as a whole; it was followed by an onslaught on the *Quarterly*. Other articles dealt with English history and with ecclesiastical establishments, which he severely impugned. To a periodical of short duration, *The Parliamentary History and Review*, he contributed an elaborate political retrospect of the parliament of 1820–26. In 1829 appeared the *Analysis of the Human Mind*. From 1831 to 1833 he was largely occupied in the defence of the East India Company during the controversy attending the renewal of its charter, he being in virtue of his office the spokesman of the court of directors. In 1834 Sir William Molesworth projected the *London Review*, and Mill contributed to it during the last two years of his life. His most notable article was one entitled "The Church and its Reform," which was much too sceptical for the time, and injured the *Review*. His last published book was the *Fragment on Mackintosh*, which appeared in 1835. He died on the 23d June 1836.

A considerable space would be required to do justice to Mill's character—intellectual and moral—as shown both in his writings and in his intensely active and influential career. He was an excellent scholar, in the sense of knowing the Greek and Roman classics. His other accomplishments included general history, the philosophy of politics in the most comprehensive acceptation, logic, ethics, and mental philosophy. The type of his intellect was logical in the highest degree; he was, above all things, clear and precise, an enemy of every form of looseness of reasoning, and a crusher of prevailing fallacies. This is the most notable feature in his writings throughout. His was also an original mind. Except in a few subjects, which had been so well elaborated by Bentham that he was content to be little more than an expounder of Bentham's views, he gave a fresh turn to whatever topic he took up. At a time when social subjects were subjected almost exclusively to an empirical handling, he insisted on bringing first principles to bear at every point; in this lay both his strength and his weakness.

His greatest literary monument is the *History of India*. The materials for narrating the acquisition by England of its Indian empire were put into shape for the first time; a vast body of political theory was brought to bear on the delineation of the Hindu civilization; and the conduct of the actors in the successive stages of the conquest and administration of India was subjected to a severe criticism. The work itself, and the author's official connexion with India for the last seventeen years of his life, effected a complete change in the whole system of governing that country.

Mill played a great part as a politician and political philosopher in English affairs as well. He was, more than any other man, the founder of what was called philosophical radicalism. His writings on government and his personal influence among the Liberal politicians of his time determined the change of view from the French Revolution theories of the rights of man and the absolute equality of men to the claiming of securities for good government through a great extension of the electoral suffrage. Under this banner it was that the Reform Bill was fought and won.

His work on *Political Economy* was intended as a text-book of the subject, and shows all the author's precision and lucidity. It followed up the views of Ricardo, with whom Mill was in habitual intimacy. It urged strongly the modern application of the principle of population, and started the doctrine of taxing land for the unearned increment of value.

By his *Analysis of the Mind* and his *Fragment on Mackintosh* Mill acquired a position in the history of psychology and ethics. Attached to the *a posteriori* school, he vindicated its claims with conspicuous ability. He took up the problems of mind very much after the fashion of the Scotch school, as then represented by Reid, Stewart, and Brown, but made a new start, due in part to Hartley, and still more to his own independent thinking. He carried out the principle of association into the analysis of the complex emotional states, as the affections, the æsthetic emotions, and the moral sentiment, all which he endeavoured to resolve into pleasurable and painful sensations. But the salient merit of the *Analysis* is the constant endeavour after precise definition of terms and clear statement of doctrines. The *Fragment on Mackintosh* is a severe exposure of the flimsiness and misrepresentations of Mackintosh's famous dissertation on ethical philosophy. It discusses, in a very thorough way, the foundations of ethics from the author's point of view of utility.

Mill's influence on the young men of his time by his conversation has been especially celebrated. Among those that came under this influence were some of the greatest names in the generation that succeeded him. He had himself a very high ideal of public virtue, which he carried out, at the risk of sacrificing all his chances of worldly advancement, and he impressed this ideal on those that surrounded him,—most of all on his own son, who has since eclipsed his father in fame, if not in genius.

See J. S. Mill's *Autobiography*, Bain's *Life of James Mill*, G. S. Bower's *Hartley and James Mill*. (A. B.*)

MILL, John (*c.* 1645–1707), editor of an historically important critical edition of the New Testament, was born about 1645 at Shap in Westmoreland, entered Queen's College, Oxford, as a servitor in 1661, and took his master's degree in 1669. Soon afterwards he was chosen fellow and tutor of his college; in 1676 he became chaplain to the bishop of Oxford, and in 1681 he obtained the rectory of Blechingdon, Oxfordshire, and was made chaplain to Charles II. From 1685 till his death he held the appointment of principal of St Edmund's Hall; and in 1704 he was nominated by Queen Anne to a prebendal stall in Canterbury. He died on June 23, 1707, just a fortnight after the publication of his Greek Testament.

Mill's *Novum Testamentum Græcum, cum lectionibus variantibus MSS. Exemplarium, Versionum, Editionum SS. Patrum et Scriptorum Ecclesiasticorum, et in easdem notis* (Oxford, fol. 1707), was undertaken by the advice and encouragement of Fell, his predecessor in the field of New Testament criticism; it represents the labour of thirty years, and is admitted to mark a great advance on all that had previously been achieved. The text indeed is that of R. Stephanus (1550), but the notes, besides embodying all previously existing collections of various readings, add a vast number derived from his own examination of many new MSS. and Oriental versions (the latter unfortunately he used only in the Latin translations). He was the first to notice, though only incidentally, the value of the concurrence of the Latin evidence with the Codex Alexandrinus, the only representative of an ancient non-Western Greek text then sufficiently known; this hint was not lost on Bentley (see Westcott and Hort, *Introduction to New Testament*). Mill's various readings, numbering about thirty thousand, were attacked by Whitby in his *Examen* as destroying the validity of the text; Antony Collins also argued in the same sense though with a different object. The latter called forth a reply from Bentley (*Phileleutherus Lipsiensis*). In 1710 Kuster reprinted Mill's Testament at Amsterdam with the readings of twelve additional MSS.

MILL, John Stuart (1806–1873), son of James Mill (*q.v.*), was born in London on the 20th May 1806. His education was from first to last undertaken by his father, and is likely long to remain a standing subject for wonder and discussion. Much of the wonder is no doubt due to his father's monstrous inversion of custom, the boy being set almost as soon as he could speak to work at our time-honoured subjects of secondary and higher education. He was taught the Greek alphabet at the age of three, and one of his earliest recollections, as he has recorded in his autobiography, was learning lists of common Greek words with their English meanings, written for him by his father on cards. By his eighth year he had gone through in the original a great many Greek books. "Of grammar," he says, "until some years later, I learnt no more than the inflexions of the nouns and verbs, but after a course of vocables proceeded at once to translation; and I faintly

remember going through *Æsop's Fables*, the first Greek book which I read. The *Anabasis*, which I remember better, was the second. I learnt no Latin until my eighth year. At that time I had read under my father's tuition a number of Greek prose authors, among whom I remember the whole of Herodotus and of Xenophon's *Cyropædia* and *Memorials of Socrates*, some of the lives of the philosophers by Diogenes Laertius, part of Lucian, and Isocrates *Ad Demonicum* and *Ad Nicoclem*. I also read, in 1813, the first six dialogues (in the common arrangement) of Plato, from the *Euthyphron* to the *Theætetus* inclusive." Besides all these Greek books, he had read a great deal of history in English—Robertson's histories, Hume, Gibbon, Watson's *Philip II. and III.*, Hooke's *Roman History*, Rollin's *Ancient History*, Langhorne's *Plutarch*, Burnet's *History of My Own Times*, thirty volumes of the *Annual Register*, Millar's *Historical View of the English Government*, Mosheim's *Ecclesiastical History*, M'Crie's *Knox*, and two histories of the Quakers.

That Mill "knew Greek" and "read Plato" before he was eight years old is often repeated, sometimes as an instance of amazing precocity, sometimes as an awful example of injudicious parental forcing. The astonishment that a child should have done so much at such an age is probably as little grounded in reason as was Mill's own opinion that any child might have done the same. It is forgotten that many thousands of persons have known Greek before the age of eight without a knowledge of the technicalities of Greek grammar. In presence of the fact that Mill was never distinguished for great memory of detail or richness of historical or literary allusion, it is a fair conclusion that the matter of his reading at this age was of as little service to him in after life as if he had read the trashiest of boy's own books. This is not to say that for educational purposes his early years were wasted as in his own and his father's opinion they generally are. But undoubtedly the main factor in Mill's education was not the literature put into his hands, but his constant intercourse with the active richly stored mind and strenuous character of his father. If any should be tempted to imitate the method, they should bear in mind that this was the cardinal element of it. The tutor was of more importance than the books. The reading of Plato's dialogues would have been only an exercise in rough translation if the boy had not had a Socrates with him in living communion. The child was a constant inmate of his father's study, and trotted by his side in his walks, giving from jottings on slips of paper as good an account as he could of what he had read. He thus learnt at an unusually early age by example, precept, and practice the habit of strenuous application to difficult work. The fact that Mill was taught thus early to take his chief pleasure in overcoming intellectual difficulties, and to realize the meaning of general terms, accounts for the singular and altogether unparalleled ease which he acquired in the treatment of political and social generalizations, not in barren abstract vagueness, but in close relation with facts. This on the intellectual side; and on the moral side the child was almost from the dawn of consciousness instructed to regard himself as consecrated to a life of labour for the public good; his ambition was kindled to follow in the footsteps of the great men of all ages, and at the same time the utmost care was taken to purify that ambition from unworthy motives.

A contemporary record of Mill's studies from eight to thirteen is published in Dr Bain's sketch of his life. It shows that the *Autobiography* rather understates than overstates the amount of work done. At the age of eight he began Latin, Euclid, and algebra, and was appointed schoolmaster to the younger children of the family—a post, he hints, more serviceable to his intellect than to his manners. His main reading was still history, but he went through all the Latin and Greek authors commonly read in the schools and universities, besides several that are not commonly read by undergraduates. He was not taught to compose either in Latin or in Greek, and he was never an exact scholar in the academic sense; it was for the subject-matter that he was required to read, and by the age of ten he could read Plato and Demosthenes with ease. His father's *History of India* was published in 1818; immediately thereafter, about the age of twelve, John, under his energetic direction, began a thorough study of the scholastic logic, at the same time reading Aristotle's logical treatises in the original. In the following year he was introduced to political economy. And there, when the pupil was nearly fourteen, this remarkable education terminated. From that time he worked less immediately under his father's eye. It was an inevitable incident of such an education that Mill should acquire many of his father's speculative opinions, and his father's way of defending them. But his mind did not receive the impress passively and mechanically. "One of the grand objects of education," according to the elder Mill, "should be to generate a constant and anxious concern about evidence"; and he laboured with all the energy of his strong will against allowing his son to become a parrot of his own opinions and arguments. The duty of collecting and weighing evidence for himself was at every turn impressed upon the boy; he was taught to accept no opinion upon authority; he was soundly rated if he could not give a reason for his beliefs. John Stuart Mill was deliberately educated as an apostle, but it was as an apostle of reasoned truth in human affairs, not as an apostle of any system of dogmatic tenets. It was purposely to prevent any falling off from this high moral standard till it should become part of his being that his father kept the boy so closely with himself. Much pity has been expressed over the dreary cheerless existence that the child must have led, cut off from all boyish amusements and companionship, working day after day on his father's treadmill; but a childhood and boyhood spent in the daily enlargement of knowledge, with the continual satisfaction of difficulties conquered, buoyed up by day-dreams of emulating the greatest of human benefactors, need not have been an unhappy childhood,—and Mill expressly says that his was not unhappy. It seems unhappy only when we compare it with the desires of childhood left more to itself, and when we decline to imagine its peculiar enjoyments and aspirations. Mill complains that his father often required more than could reasonably be expected of him, but his tasks were not so severe as to prevent him from growing up a healthy, hardy, and high-spirited boy, though he was not constitutionally robust, and his tastes and pursuits were so different from those of other boys of the same age.

Most of Mill's fifteenth year was spent in France in the family of Sir Samuel Bentham. Away from his father, he maintained his laborious habits; the discipline held. Copious extracts from a diary kept by him at this time are given by Dr Bain, and show how methodically and incessantly he read and wrote, studied botany, tackled advanced mathematical problems, made notes on the scenery and the people and customs of the country. On his return in 1821 he continued his old studies with the addition of some new ones. One of the new studies was Roman law, which he read with John Austin, his father having half decided on the bar as the best profession open to him. Another was psychology. In 1823, when he had just completed his seventeenth year, the notion of the bar as a livelihood was abandoned, and he entered as a clerk in the examiner's office of the India House, "with the under-

standing that he should be employed from the beginning in preparing drafts of despatches, and be thus trained up as a successor to those who then filled the highest departments of the office."

Mill's work at the India House, which was henceforth his livelihood, did not come before the public, and those who have scouted his political writings as the work of an abstract philosopher, entirely unacquainted with affairs, have ignored the nature of his duties. From the first he was more than a clerk, and after a short apprenticeship he was promoted, in 1828, to the responsible position of assistant-examiner. The duty of the so-called examiners was to examine the letters of the agents of the Company in India, and to draft instructions in reply. The character of the Company's government was almost entirely dependent upon their abilities as statesmen. For twenty years, from 1836 to 1856, Mill had charge of the Company's relations with the native states. In the hundreds of despatches that he wrote in this capacity, much, no doubt, was done in accordance with established routine, but few statesmen of his generation had a wider experience of the responsible application of principles of government to actual emergencies. That he said so little about this work in the *Autobiography* was probably because his main concern there was to expound the influences that affected his moral and mental development. A man of different temperament might have found abundance of dramatic interest in watching the personal and political changes in so many distinct states. But Mill makes no reminiscences of this kind, nor does he give any clue to the results of his own initiative.

To return to his extra-official activity, which received an immense impulse about the time of his entering the India House from what must strike a man of the world as a strange source. The reading of Dumont's exposition of Bentham's doctrines in the *Traité de Législation* was an epoch in Mill's life. It awoke in him an ambition as enthusiastic and impassioned as a young man's first love. The language that he uses about it in his autobiography reveals a warmth of inner life that few people would suspect from the record of his dry studies. When he laid down the last volume, he says, he had become a different being. It gave unity to the detached and fragmentary component parts of his knowledge and beliefs. "I now had opinions—a creed, a doctrine, a philosophy—in one among the best senses of the word, a religion, the inculcation and diffusion of which could be made the principal outward purpose of a life. And I had a grand conception laid before me of changes to be effected in the condition of mankind through that doctrine." He had been carefully bred to contemplate work for human welfare as the ruling motive of his life; that motive had now received definite direction.

Many a youth has entered the world with ambition equally high, but few have felt as Mill felt the first shock of despair, and fewer still have rallied from that despair with such indomitable resolution. The main secret of the great "crisis" of his youthful life is probably to be found in the lofty ardour of the aspirations then conceived and shaped. For four years he worked with faith and hope in his mission, and these were years of incessant propagandist activity. The enthusiast of seventeen, burning to reorganize human affairs so as to secure the greatest happiness of the greatest number, set siege to the public mind through several approaches. He constituted a few of his youthful friends, imbued with the principles of his new creed, into a society which he called the "Utilitarian" Society, taking the word, as he tells us, from one of Galt's novels. Two newspapers were open to him—the *Traveller*, edited by a friend of Bentham's, and the *Chronicle*, edited by his father's friend Black. One of his first efforts was a solid argument for freedom of discussion, in a series of letters to the *Chronicle* apropos of the prosecution of Richard Carlile. But he watched all public incidents with a vigilant eye, and seized every passing opportunity of exposing departures from sound principle in parliament and courts of justice. Another outlet was opened up for him in 1824 by the starting of the *Westminster Review*, and still another in the following year in the *Parliamentary History and Review*. This year also he found a congenial occupation in editing Bentham's *Rationale of Judicial Evidence*. Into this he threw himself with zeal. And all the time, his mind full of public questions, he discussed and argued eagerly with the many men of promise and distinction who came to his father's house. He engaged in set discussions at a reading society formed at Grote's house in 1825, and in set debates at a Speculative Society formed in the same year.

"A very disquisitive youth," was Peacock's description of young Mill at this period, and this was probably how the enthusiast struck most of his outside acquaintances. But the glow of a great ambition as well as the energy of a piercing intellect might have been felt in his writings. His mission was none the less arduous that he proposed to convert the world by reason. Only the fulness of unbroken hope could have supported his powers, if he had had a frame of iron, under the strain of such incessant labour. All of a sudden, a misgiving which he compares to the Methodist's "first conviction of sin" made a rift in the wholeness of his faith in his mission. "It was in the autumn of 1826. I was in a dull state of nerves, such as everybody is occasionally liable to; unsusceptible to enjoyment or pleasurable excitement; one of those moods when what is pleasure at other times becomes insipid or indifferent. . . . . In this frame of mind it occurred to me to put the question directly to myself, 'Suppose that all your objects in life were realized, that all the changes in institutions and opinions which you are now looking forward to could be completely effected at this very instant, would this be a great joy and happiness to you?' And an irrepressible self-consciousness distinctly answered, 'No!' At this my heart sank within me; the whole foundation on which my life was constructed fell down. All my happiness was to have been found in the continual pursuit of this end. The end had ceased to charm, and how could there ever again be any interest in the means? I seemed to have nothing left to live for."

The passage in his autobiography in which Mill gives an account of this prostrating disenchantment and his gradual release from its benumbing spell is one of the most interesting chapters in personal history. The first break in the gloom came, he tells us, from his reading in Marmontel's *Mémoires* "the passage which relates his father's death, the distressed position of the family, and the sudden inspiration by which he, then a mere boy, felt and made them feel that he would be everything to them—would supply the place of all that they had lost." Mill was moved to tears by the narrative, and his burden grew lighter at the thought that all feeling was not dead within him, that he was not a mere intellectual machine. This incident, and the delight that he now began to take in Wordsworth's "Poems founded on the Affections," gives a clue to one of the secrets of Mill's despondency. It was an unsatisfied longing for personal affection, for love and friendship, of which his life hitherto had been barren. His father seems to have been reserved, undemonstrative even to the pitch of chilling sternness in his intercourse with his family; and among young Mill's comrades contempt of feeling was almost a watchword, because it is so often associated with mischievous prejudice and wrong conduct. Himself absorbed in abstract questions and pro-

jects of general philanthropy, he had been careless of winning or keeping personal attachment. But it was not till despair first seized him, as he looked back at the poverty of the results of his work as an apostle, that Mill began to feel the void in his affections and the need of human sympathy. We must remember how little when his ambition was formed he knew of the living world around him. He knew in terms that political and social change must be slow; he could whisper patience to himself, and say to himself that his life must be happy because the attainment of his great object must occupy the whole of it; but without experience he could not have been prepared for the actual slowness of the reformer's work, or armed against its terribly oppressive influence. Inevitably he underrated the stolidity and strength of the forces arrayed against him. Four years seems a long time at that age. In 1826 Mill could look back to four years of eager toil. What were the results? He had become convinced that his comrades in the Utilitarian Society, who never numbered more than ten, had not the stuff in them for a world-shaking propaganda; the society itself was dissolved; the *Parliamentary Review* was a failure; the *Westminster* did not pay its expenses; Bentham's *Judicial Evidence* produced little effect on the reviewers. His own reception at the Speculative Debating Society, where he first measured his strength in public conflict, was calculated to produce self-distrust. He found himself looked upon with curiosity as a precocious phenomenon, a "made man," an intellectual machine set to grind certain tunes. The most clear and cogent reasoning failed to sway his audience. Great things had been expected of this society as a means of bringing together for close discussion the leading young men then in public life or looking forward to it. Its first session proved a fiasco. The leaders that had been expected stayed away. With these repulses to his hopes along the whole line of his activity, Mill must also have suffered from the nervous exhaustion that only the hope and heat of the fight had kept him from feeling before. No wonder that he was disheartened, began to feel defects in his father's training, to question and analyse his own faith, to yearn for the solace of personal affection, and to reconstitute his scheme of life.

That in spite of this rude shock the foundations laid by his early training remained stable appears from the facts that all through the period of his gloom he continued working as before, and that he considered himself bound, once convinced that his old plan of life was insufficient, to build up a thoroughly reasoned new plan wherewith to give new heart and hope to his work. The new system was much less different from the old than might be supposed from what he says of the struggle that it cost him to reach it. Regard for the public good was still his religion, the ruling motive that gave unity to his conduct. But he now recognized that this was too vague and insubstantial an object to be sufficient of itself for the satisfaction of a man's affections. It is a proof of the dominating force of his father's character that it cost the younger Mill such an effort to shake off his stern creed about poetry and personal emotion. Like Plato, the elder Mill would have put poets under ban as ministers of prejudice and enemies of truth. And he often insisted on the wisdom of restricting as much as possible the private affections, while expanding as much as possible the public affections. Landor's maxim of "few acquaintances, fewer friends, no familiarities" had his cordial approval. These doctrines the younger Mill at first took up with boyish enthusiasm and pedantry, but it was against this part of his father's creed that he now felt himself forced in reason to revolt. He stood too much in awe of his father to make him the confidant of his difficulties. He wrestled with them in the gloomy solitude of his own mind. He was victorious; he reached firm ground at last; but the struggle left him in several respects changed. He carried out of the struggle as the fruits of victory a more catholic view of the elements of human happiness, a delight in the poetry of nature and the affections as well as the poetry of heroic unselfish character and action, a disposition to study more sympathetically the point of view of opponents, a more courteous style of polemic, a hatred of sectarianism, an ambition no less noble and disinterested but moderated to practical possibilities.

In the course of the next few years Mill wrote comparatively little, but he "carried on," as he says, "a quantity of thinking respecting a host of subjects." It was a period of search, deliberation, germination, and striking root. Coincident if not causally connected with the relief from his spiritual crisis came his first consciousness of power as "an original and independent thinker." In the dialectic conversations with a small band of students at Grote's house, he regained the self-confidence that had been shaken in the larger and rougher arena of the Speculative Debating Society. The beginning of his works on logic and political economy may be traced back to those discussions, and he learnt from them, he tells us, the habit of "never accepting half solutions of difficulties as complete; never abandoning a puzzle, but again and again returning to it until it was cleared up; never allowing obscure corners of a subject to remain unexplored, because they did not appear important; never thinking that he perfectly understood any part of a subject until he understood the whole." He learnt also an important moral lesson from the Speculative Society, besides learning the strong points of other political and social creeds and the weak points of Benthamism from defending it point by point against all comers. With all his despondency, he did not abandon the meetings of the society after the fiasco of the first session. He stood by it firmly, and in a short time had the triumph of seeing its debates famous enough to attract men with whom it was profitable for him to interchange opinions, among others Maurice and Sterling. He ceased to attend the society in 1829, but he carried away from it the strengthening memory of failure overcome by persevering effort, and the important doctrinal conviction that a true system of political philosophy was "something much more complex and many-sided than he had previously had any idea of, and that its office was to supply, not a set of model institutions, but principles from which the institutions suitable to any given circumstances might be deduced."

The first sketch of Mill's political philosophy appeared in a series of contributions to the *Examiner* in the autumn of 1830 on "Prospects in France." He was in Paris soon after the July Revolution, made the acquaintance of the leading spirits among the younger men; and in his discussion of what they were doing and what they should do in making a new constitution we find the germs of many thoughts afterwards more fully developed in his *Representative Government.*

The division of a man's life into periods must always be a rough partition, but we may conveniently and with tolerable accuracy take these letters as marking the close of his period of meditative search, of radication, and his return to hopeful aspiring activity. It was characteristic of the nature of the man that he should be stirred to such delight by the Revolution in France, and should labour so earnestly to make his countrymen understand with what gravity and sobriety it had been effected. Their own Reform Bill came soon after, and it is again characteristic of Mill—at once of his enthusiasm and of his steady determination to do for humanity the work that nobody else

seemed able or willing to do—that we find him in the heat of the struggle in 1831 writing to the *Examiner* a series of letters on "The Spirit of the Age" which drew from Carlyle the exclamation, "Here is a new mystic!" We can easily see now what it was in these remarkable essays that fascinated Carlyle; it was the pervading opinion that in every natural state of society power must be in the hands of the wisest. This was the condition of stability; when power and wisdom ceased to coincide, there was a disturbance of the equilibrium till this coincidence was again effected. But whether Carlyle was right in the epithet "mystic" may be judged from the fact that Mill's inductive logic was the direct result of his aspirations after political stability as determined by the dominion of the wisest. "Why is it," he asked, "that the multitude accept implicitly the decisions of the wisest, of the specially skilled, in physical science?" Because in physical science there is all but complete agreement in opinion. "And why this agreement?" Because all accept the same methods of investigation, the same tests of truth. Is it possible then to obtain unanimity as to the methods of arriving at conclusions in social and political matters, so as to secure similar agreement of opinion among the specially skilled, and similar general respect for their authority? The same thought appears in a review of Herschel's *Natural Philosophy*, written about the same time. Mill remarks that the uncertainty hanging over the very elements of moral and social philosophy proves that the means of arriving at the truth in those sciences are not yet properly understood. "And whither," he adds, "can mankind so advantageously turn, in order to learn the proper means, and to form their minds to the proper habits, as to that branch of knowledge in which by universal acknowledgment the greatest number of truths have been ascertained, and the greatest possible degree of certainty arrived at?"

By 1831 Mill's enthusiasm for humanity had been thoroughly reawakened, and had taken the definite shape of an aspiration to supply an unimpeachable method of search for conclusions in moral and social science. From the platform on which Carlyle and Mill met in 1831 they travelled different roads,—the one to preach the duty of obedience to the wisest, the other to search for a means by which wisdom might be acquired such as would command respect and win the assent of free conviction. No mystic ever worked with warmer zeal than Mill. But his zeal encountered a check which baffled him for several years, and which left its mark in various inconsistencies and incoherences in his completed system. He had been bred by his father in a great veneration for the syllogistic logic as an antidote against confused thinking. He attributed to his early discipline in this logic an impatience of vague language which in all likelihood was really fostered in him by his study of the Platonic dialogues and of Bentham, for he always had in himself more of Plato's fertile ingenuity in canvassing the meaning of vague terms than the schoolman's rigid consistency in the use of them. Be this as it may, enthusiastic as he was for a new logic that might give certainty to moral and social conclusions, Mill was no less resolute that the new logic should stand in no antagonism to the old. In his *Westminster* review of Whately's *Logic* in 1828 (invaluable to all students of the genesis of Mill's logic) he appears, curiously enough, as an ardent and brilliant champion of the syllogistic logic against highfliers such as the Scotch philosophers who talk of "superseding" it by "a supposed system of inductive logic." His inductive logic must "supplement and not supersede." It must be concatenated with the syllogistic logic, the two to be incorporated in one system. But for several years he searched in vain for the means of concatenation.

Meantime, while recurring again and again, as was his custom, to this cardinal difficulty, Mill worked indefatigably in other directions where he saw his way clear, expatiating over a wide range of political, social, economical, and philosophical questions. The working of the new order in France, and the personalities of the leading men, had a profound interest for him; he wrote on the subject in the *Examiner*. He had ceased to write for the *Westminster* in 1828; but during the years 1832 and 1833 he contributed many essays to *Tait's Magazine*, the *Jurist*, and the *Monthly Repository*. In 1835 the *London Review* was started, with Mill as editor; it was amalgamated with the *Westminster* in 1836, and Mill continued editor till 1840. Much of what he wrote then was subsequently incorporated in his systematic works; some of his essays were reprinted in his first two volumes of *Dissertations and Discussions* (1859). The essays on Bentham and Coleridge constituted the first manifesto of the new spirit which Mill sought to breathe into English Radicalism. But the reprinted papers give no just idea of the immense range of Mill's energy at this time. His position in the India Office, where alone he did work enough for most men, cut him off from entering parliament; but he laboured hard though ineffectually to influence the legislature from without by combating the disposition to rest and be thankful. In his *Autobiography* he admits that the attempt to form a Radical party in parliament at that time was chimerical.

It was in 1837, on reading Whewell's *Inductive Sciences* and re-reading Herschel, that Mill at last saw his way clear both to formulating the methods of scientific investigation and joining on the new logic as a supplement to the old. Epoch-making as his logic undoubtedly was, from the multitude of new views opened up, from the addition of a new wing to the rambling old building, and from the inspiring force with which every dusty chamber was searched into and illuminated, Mill did not escape all the innumerable pitfalls of language that beset the pioneer in such a subject. It is evident from a study of his purposes and the books from which he started that his worst perplexities were due to his determination to exhibit scientific method as the complement of scholastic logic. In his defence of the syllogism he confounds the syllogistic forms with deductive reasoning. Every deductive reasoning may be thrown into the form of a syllogism, but not every syllogism is deductive. The reasoning in several of the syllogistic forms is not deductive at all in the sense of involving a movement from general to particular. Although he knew Aristotle in the original, Mill did not recognize the fact that the syllogistic machinery was primarily constructed for the reasoning together of terms. As regards the word induction, Mill uses it in different connexions to cover three or four distinguishable meanings—induction viewed as the establishment of predications about a general term, induction viewed as inference from the known to the unknown, induction viewed as verification by experiment, and induction viewed as the proof of propositions of causation. The form of his system was really governed by the scholastic notion of induction as a means of establishing general propositions; the inductive part of his system is introduced after the deductive under this character; while the greater portion of the substance of what he treats of under the name of induction, and especially the so-called experimental methods, have nothing whatever to do with the establishment of general propositions, in the technical sense of general propositions.

But the permanent value and influence of Mill's inductive logic is not to be measured by technical inaccuracies and inconsistencies, to which an academic mind may easily attach undue importance. In the technical history of the science, Mill's *Logic* may be viewed as an attempt to fuse

the practical tests of truth set forth in Herschel's *Discourse on Natural Philosophy* with the theoretic views of induction propounded in Whately's *Logic*. But in the history of thought the great importance of the work is due not so much to its endeavour to formulate the methods of science and lay bare the first principles on which they rest as to its systematic application of scientific method to what he called the moral sciences. Mill has often been criticized as if he had pretended to teach men how to conduct their investigations and how to make discoveries in the physical sciences. His work was rather to educe from the practice of men of science the principles on which they proceed in testing and proving their speculations concerning cause and effect in the physical world, and see whether the same principles could not be applied in testing and proving speculations concerning cause and effect in the moral world. What is the effect upon human character and human happiness of given social and physical conditions—climate, institutions, customs, laws? How can conclusions upon such points be proved? These were the questions in which Mill was interested, and the striking novelty of his work was its endeavour to show that propositions of cause and effect in human affairs must be proved, if they admit of proof at all, absolute or approximate, on the same principles with propositions of cause and effect in the material world.

The *Logic* was published in 1843. In 1844 appeared his *Essays on Some Unsettled Questions in Political Economy*. These essays were worked out and written many years before, and show Mill in his first stage as a political economist. Four out of the five essays are elaborate and powerful solutions of perplexing technical problems—the distribution of the gains of international commerce, the influence of consumption on production, the definition of productive and unproductive labour, the precise relations between profits and wages. Though Mill appears here purely as the disciple of Ricardo, striving after more precise statement, and reaching forward to further consequences, we can well understand in reading these essays, searching, luminous, large and bold in outline, firmly wrought in detail, how about the time when he first sketched them he began to be conscious of power as an original and independent thinker.

That originality and independence became more conspicuous when he reached his second stage as a political economist, struggling forward towards the standpoint from which his systematic work was written. It would seem that in his fits of despondency one of the thoughts that sat upon him like a nightmare and marred his dreams of human improvement was the apparently inexorable character of economic laws, condemning thousands of labourers to a cramped and miserable existence, and thousands more to semi-starvation. From this oppressive feeling he found relief in the thought set forth in the opening of the second book of his *Political Economy*—that, while the conditions of production have the necessity of physical laws, the distribution of what is produced among the various classes of producers is a matter of human arrangement, dependent upon alterable customs and institutions. There can be little doubt that this thought, whether or not in the clear shape that it afterwards assumed, was the germ of all that is most distinctive in his system of political economy. It was as far as possible from the rigidity of his method of exposition to fall into the confusion of supposing that it was for political economy to discuss the equity of different modes of distribution, or the value of other objects of human endeavour conflicting with the production of wealth; but he put economic inquiries clearly in their proper place as leading to conclusions that were not always final and binding on the practical statesman, but had to be taken with other considerations as governing rational human action. Besides thus putting political economy in its just correlation with other parts of social science and conduct, Mill widened the scope of economic inquiries by discussing the economic consequences of various ideal social arrangements, and more especially different modes of distributing produce between landlord, capitalist, and labourer. Mill certainly redeemed political economy from the reproach of being a dry science. Nobody with any interest in human improvement can read his work with indifference. And he did this without in any way disturbing the original conception of political economy as the science of cause and effect in the production of wealth. One of his most eminent successors, the late Professor Cairnes, thus admirably summed up his work as a political economist:—"As he himself used to put it, Ricardo supplied the backbone of the science; but it is not less certain that the limbs, the joints, the muscular developments—all that renders political economy a complete and organized body of knowledge—have been the work of Mill."

While his great systematic works were in progress, Mill wrote very little on events or books of the day. He turned aside for a few months from his *Political Economy* during the winter of the Irish famine (1846–47) to advocate the creation of peasant-proprietorships as a remedy for distress and disorder in Ireland. He found time also to write elaborate articles on French history and Greek history in the *Edinburgh Review* apropos of Michelet, Guizot, and Grote, besides some less elaborate essays.

The *Political Economy* was published in 1848. Mill could now feel that the main work he had proposed for himself was accomplished; but, though he wrote comparatively little for some years afterwards, he remained as much as ever on the alert for opportunities of useful influence, and pressed on with hardly diminished enthusiasm in his search for useful truth. Among other things, he made a more thorough study of socialist writers, with the result that, though he was not converted to any of their schemes as being immediately practicable, he began to look upon some more equal distribution of the produce of labour as a practicability of the remote future, and to dwell upon the prospect of such changes in human character as might render a stable society possible without the institution of private property. This he has called his third stage as a political economist, and he says that he was helped towards it by the lady, Mrs Taylor, who became his wife in 1851, and with whom he had lived in intimate friendship for more than twenty years before. It is generally supposed that he writes with a lover's extravagance about this lady's powers when he compares her with Shelley and Carlyle. But a little reflexion will show that he wrote with his usual accuracy and sobriety when he described her influence on him. He expressly says that he owed none of his technical doctrine to her, that she influenced only his ideals of life for the individual and for society; and his language about her is really only a measure of the importance that he attached to such ideals above any systems of reasoned truth. There is very little propositional difference between Mill and his father; but it is obvious from what he says that his inner life became very different after he threw off his father's authority. This new inner life was strengthened and enlarged by Mrs Taylor. We must remember also that Mill in his early years had been so strictly secluded from commonplace sentiment that what the general world would consider commonplace must have come to him with all the freshness of a special revelation.

During the seven years of his married life Mill published less than in any other period of his career, but four of his

generally regarded as the main causes of his defeat in the general election of 1868. But, as he suggests himself, his studied advocacy of unfamiliar projects of reform had made him unpopular with "moderate Liberals." When he was first elected on a sudden impulse of enthusiasm, extremely little was known about him by the bulk of the electorate; and his writing about checks against democracy had prepared many for a more conservative attitude on questions of practical politics. He retired with a sense of relief to his cottage and his literary life at Avignon. His parliamentary duties and the quantity of correspondence brought upon him by increased publicity had absorbed nearly the whole of his time. The scanty leisure of his first recess had been devoted to writing his St Andrews rectorial address on higher education and to answering attacks on his criticism of Hamilton; of the second, to annotating, in conjunction with Mr Bain and Mr Findlater, his father's *Analysis of the Mind*. But now he could look forward to a literary life pure and simple, and his letters show how much he enjoyed the change. His little cottage was filled with books and newspapers; the beautiful country round it furnished him with a variety of walks; he read, wrote, discussed, walked, botanized. His step-daughter, Miss Taylor, his constant companion after his wife's death, "architect and master-mason all in one," carried out various improvements in their quiet home for the philosopher's comfort. "Helen," he wrote to Mr Thornton, "has carried out her long-cherished scheme (about which she tells me she consulted you) of a 'vibratory' for me, and has made a pleasant covered walk, some 30 feet long, where I can vibrate in cold or rainy weather. The terrace, you must know, as it goes round two sides of the house, has got itself dubbed the 'semi-circumgyratory.' In addition to this Helen has built me a herbarium, a little room fitted up with closets for my plants, shelves for my botanical books, and a great table whereon to manipulate them all. Thus, you see, with my herbarium, my vibratory, and my semi-circumgyratory, I am in clover; and you may imagine with what scorn I think of the House of Commons, which, comfortable club as it is said to be, could offer me none of these comforts, or, more perfectly speaking, these necessaries of life." Mill was an enthusiastic botanist all his life long, and a frequent contributor of notes and short papers to the *Phytologist*. One of the things that he looked forward to during his last journey to Avignon was seeing the spring flowers and completing a flora of the locality. His delight in scenery frequently appears in letters written to his friends during his summer and autumn tours.

No recluse ever had a more soothing retreat than Mill's Avignon cottage, but to the last he did not relax his laborious habits nor his ardent outlook on human affairs. The essays in the fourth volume of his *Dissertations*—on endowments, on land, on labour, on metaphysical and psychological questions—were written for the *Fortnightly Review* at intervals after his short parliamentary career. One of his first tasks was to send his treatise on the *Subjection of Women* through the press. The essay on *Theism* was written soon after. The last public work in which he engaged was the starting of the Land Tenure Reform Association. The interception by the state of the unearned increment, and the promotion of co-operative agriculture, were the most striking features in his programme. He wrote in the *Examiner* and made a public speech in favour of the association a few months before his death. The secret of the ardour with which he took up this question probably was his conviction that a great struggle was impending in Europe between labour and capital. He regarded his project as a timely compromise.

Mill died at Avignon on the 8th of May 1873.

Within the limits of this article it is impossible to attempt a criticism of Mill's conclusions in so many fields of research; one must be content with trying to indicate the purpose and the spirit of his work. Perhaps we still stand too near to judge without bias; some years hence men will be better able to say whether he made sciolism less reckless or brought mankind appreciably nearer that dominion of the wisest which was the remote goal of his endeavour. It will be long before humanity finds a nobler example of the searcher after the best means of social improvement. He sought after clear ideas with the ardour of a mystic, the patience and laborious industry of a man of science; he encountered opponents with a generosity and a courtesy worthy of any *preux chevalier* of mediæval romance, while he was not inferior to that ideal in the vigour of his blows against injustice. As regards his influence, it has been well said that "no calculus can integrate the innumerable pulses of knowledge and of thought that he has made to vibrate in the minds of his generation." He quickened thought upon every problem that he touched. Any estimate of Mill's service to political or philosophical thought at this moment is liable to be injuriously affected by the temporary discredit into which some of his doctrines have fallen. He was not infallible; he made no claim to dogmatic authority. But in criticism of detail, according to our present light, we may easily blind ourselves to the greatness of the work that Mill accomplished in the development of opinion. (W. M.)

MILLAU, or MILHAU, capital of an arrondissement in the department of Aveyron, France, is situated on the left bank of the Tarn, half a mile below the point at which that river is joined by the Dourbie, and 48 miles to the south-east of Rodez, on the Rodez and Montpellier line. Itself 1210 feet above the level of the sea, it is overlooked by hills covered with vineyards and fruit trees or by bare and scarped rocks. The streets of Millau are narrow, and some of the houses of great antiquity, but the town is surrounded by spacious boulevards. On two sides the Place d'Armes is adorned by stone columns supporting galleries of wood; the only buildings of special interest are the Romanesque church of Notre Dame, and the belfry of the old hôtel de ville. The principal industry is the manufacture of gloves, but various branches of the leather manufacture are also carried on. The chief articles of commerce are wool (both raw and prepared), Roquefort cheese, wine, almonds, and live stock. The population in 1881 was 16,628.

The viscounts of Millau are mentioned as early as the 10th century; in the 16th it became one of the leading strongholds of the Reformed party in the south of France. Its industry suffered severely by the revocation of the edict of Nantes.

MILLENNIUM. In the history of Christianity three main forces are found to have acted as auxiliaries of the gospel. They have elicited the ardent enthusiasm of many whom the bare preaching of the gospel would never have made decided converts. These are (1) a belief in the speedy return of Christ and in His glorious reign on earth; (2) mystical contemplation, which regards heavenly blessings as a possible possession in the present life; and (3) faith in a divine predestination of some to salvation and others to perdition. Each of these forces has at particular times proved too strong for church authority and burst the embankments with which the church had at once narrowed and protected Christian life and thought. They have produced ecclesiastical, social, and political convulsions, where the elemental force of religious conviction has destroyed all organization, whether of church or of state. They have released from its fetters the free spirit of Christianity, though often enough they have associated with it a fanaticism more damaging to the gospel than the temporizing policy of the hierarchy.

First in point of time came the faith in the nearness of Christ's second advent and the establishing of His reign of glory on the earth. Indeed it appears so early that it might be questioned whether it ought not to be regarded as an essential part of the Christian religion. That question, however, will scarcely be answered in the affirmative. The ideas of the Sermon on the Mount, or the pregnant thoughts of the Pauline theology, are independent of the expectation that the kingdom of glory will shortly

be established. On the other hand, it must be admitted that this expectation was a prominent feature in the earliest proclamation of the gospel, and materially contributed to its success. If the primitive churches had been under the necessity of framing a "Confession of Faith," it would certainly have embraced those pictures by means of which the near future was distinctly realized. But then these pictures and dreams and hopes were just the things that made systematized doctrine impossible; it is possible to formulate the mythological ideas, but not the shifting imagery of the imagination.

In the anticipations of the future prevalent amongst the early Christians (*c.* 50–150) it is necessary to distinguish a fixed and a fluctuating element. The former includes (1) the notion that a last terrible battle with the enemies of God was impending; (2) the faith in the speedy return of Christ; (3) the conviction that Christ will judge all men, and (4) will set up a kingdom of glory on earth. To the latter belong views of the Antichrist, of the heathen world-power, of the place, extent, and duration of the earthly kingdom of Christ, &c. These remained in a state of solution; they were modified from day to day, partly because of the changing circumstances of the present by which forecasts of the future were regulated, partly because the indications—real or supposed—of the ancient prophets always admitted of new combinations and constructions. But even here certain positions were agreed on in large sections of Christendom. Amongst these was the expectation that the future kingdom of Christ on earth should have a fixed duration,—according to the most prevalent opinion, a duration of one thousand years. From this fact the whole ancient Christian eschatology was known in later times as "chiliasm,"—a name which is not strictly accurate, since the doctrine of the millennium was only one feature in its scheme of the future.

1. This idea that the Messianic kingdom of the future on earth should have a definite duration has—like the whole eschatology of the primitive church—its roots in the Jewish apocalyptic literature, where it appears at a comparatively late period. At first it was assumed that the Messianic kingdom in Palestine would last for ever (so the prophets; *cf.* Jerem. xxiv. 6; Ezek. xxxvii. 25; Joel iv. 20; Daniel vi. 27; Sibyll. iii. 49 *sq.*, 766; Psalt. Salom. xvii. 4; Enoch lxii. 14), and this seems always to have been the most widely accepted view (John xii. 34). But from a comparison of prophetic passages of the Old Testament learned apocalyptic writers came to the conclusion that a distinction must be drawn between the earthly appearance of the Messiah and the appearance of God Himself amongst His people and in the Gentile world for the final judgment. As a necessary consequence, a limited period had to be assigned to the Messianic kingdom. It is not altogether improbable that the mysterious references to the sufferings of the Messiah had also an influence on some minds. This, however, is doubtful. It is certain at all events that the whole conception marks the beginning of the dissolution of realistic and sensuous views of the future. The age was too advanced to regard the earthly Messianic kingdom as the end. There was an effort to find a place among the hopes of the future for those more spiritual and universal anticipations, according to which eternal and heavenly blessedness will be the portion of the faithful, this earth and heaven will pass away, and God will be all in all. As to the period to be assigned to this earthly kingdom, no agreement was ever reached in Judaism, any more than in the detailed descriptions of its joys and pleasures. According to the Apocalypse of Baruch (xl. 3) this kingdom will last "donec finiatur mundus corruptionis." In the Book of Enoch (xci. 12) "a week" is specified, in the Apocalypse of Ezra (vii. 28 *sq.*) four hundred years. This figure, corresponding to the four hundred years of Egyptian bondage, occurs also in the Talmud (Sanhedrin 99*a*). But this is the only passage; the Talmud has no fixed doctrine on the point. The view most frequently expressed there (see Von Otto in *Hilgenfeld's Zeitschrift*, 1877, p. 527 *sq.*) is that the Messianic kingdom will last for one thousand (some said two thousand) years. "In six days God created the world, on the seventh He rested. But a day of God is equal to a thousand years (Ps. xc. 4). Hence the world will last for six thousand years of toil and labour; then will come one thousand years of Sabbath rest for the people of God in the kingdom of the Messiah." This idea must have already been very common in the first century before Christ. The combination of Gen. i., Dan. ix., and Ps. xc. 4 was peculiarly fascinating.

2. Jesus Himself speaks of only one return of the Son of Man—His return to judgment. In speaking of it, and of the glorious kingdom He is to introduce, He makes use of apocalyptic images (Matt. viii. 11, xxvi. 29; Luke xxii. 16; Matt. xix. 28); but nowhere in the discourses of Jesus is there a hint of a limited duration of the Messianic kingdom. The apostolic epistles are equally free from any trace of chiliasm (neither 1 Cor. xv. 23 *sq.* nor 1 Thess. iv. 16 *sq.* points in this direction). In the Apocalypse of John, however, it occurs in the following shape (chap. xx.). After Christ has appeared from heaven in the guise of a warrior, and vanquished the antichristian world-power, the wisdom of the world, and the devil, those who have remained steadfast in the time of the last catastrophe, and have given up their lives for their faith, shall be raised up, and shall reign with Christ on this earth as a royal priesthood for one thousand years. At the end of this time Satan is to be let loose again for a short season; he will prepare a new onslaught, but God will miraculously destroy him and his hosts. Then will follow the general resurrection of the dead, the last judgment, and the creation of new heavens and a new earth. That *all* believers will have a share in the first resurrection and in the Messianic kingdom is an idea of which John knows nothing. The earthly kingdom of Christ is reserved for those who have endured the most terrible tribulation, who have withstood the supreme effort of the world-power,—that is, for those who are actually members of the church of the last days. The Jewish expectation is thus considerably curtailed in the hands of John, as it is also shorn of its sensual attractions. "Blessed and holy is he that hath part in the first resurrection; on such the second death hath no power; but they shall be priests of God and of Christ, and shall reign with Him a thousand years." More than this John does not say. But other ancient Christian authors were not so cautious. Accepting the Jewish apocalypses as sacred books of venerable antiquity, they read them eagerly, and transferred their contents bodily to Christianity. Nay more, the Gentile Christians took possession of them, and just in proportion as they were neglected by the Jews—who, after the war of Bar-Cochba, became indifferent to the Messianic hope and hardened themselves once more in devotion to the law—they were naturalized in the Christian communities. The result was that these books became "Christian" documents; it is entirely to Christian, not to Jewish, tradition that we owe their preservation. The Jewish expectations are adopted, for example, by Papias, by the writer of the epistle of Barnabas, and by Justin. Papias actually confounds expressions of Jesus with verses from the Apocalypse of Baruch, referring to the amazing fertility of the days of the Messianic kingdom (Papias in Iren. v. 33). Barnabas (*Ep.*, 15) gives us the Jewish theory (from Gen. i. and Ps. xc. 4) that the present condition of the world is to last six thousand years

The German and Swiss Reformers also believed that the end of the world was near, but they had different aims in view from those of the Anabaptists. It was not from poverty and apocalypticism that they hoped for a reformation of the church. In contrast to the fanatics, after a brief hesitation they threw millennarianism overboard, and along with it all other "opiniones Judaicæ." They took up the same ground in this respect which the Roman Catholic Church had occupied since the time of Augustine. How millennarianism nevertheless found its way, with the help of apocalyptic mysticism and Anabaptist influences, into the churches of the Reformation, chiefly among the Reformed sects, but afterwards also in the Lutheran Church, how it became incorporated with Pietism, how in recent times an exceedingly mild type of "academic" chiliasm has been developed from a belief in the verbal inspiration of the Bible, how finally new sects are still springing up here and there with apocalyptic and chiliastic expectations,—these are matters which cannot be fully entered upon here. But one remark ought to be made in conclusion. A genuine and living revival of chiliastic hopes is always a sign that the church at large has become secularized to such a degree that tender consciences can no longer feel sure of their faith within her. In this sense all chiliastic phenomena in the history of the church demand respectful attention. But when attempts are made to find room for millennarianism in a dogmatic system, it must always assume a form in which it would be utterly unrecognizable to the millennarians of the ancient church, who, just because they were millennarians, despised dogmatic, in the sense of philosophical theology. The claims of chiliasm are sufficiently met by the acknowledgment that in former times it was associated—to all appearance inseparably associated—with the gospel itself. Those who try to remodel it, so as to conserve its "elements of truth," put contempt on it while they destroy it; for it was in its day the most uncompromising enemy of all remodelling, and it can only exist along with the unsophisticated faith of the early Christians.

Cf. Schürer, *Lehrbuch der Neutestamentlichen Zeitgeschichte*, 1874, §§ 28, 29; Corrodi, *Kritische Geschichte des Chiliasmus*, 1781. A thorough history of chiliasm has not yet appeared. (A. HA.)

MILLER, HUGH (1802–1856), eminent in science and literature, and one of the most remarkable among self-taught men of genius, was born at Cromarty, on the north-east coast of Scotland, on the 10th of October 1802. His father, a sagacious and strong-willed seaman, who earned a livelihood by sailing his own sloop, perished at sea when Hugh was five years old. His mother looked much, in the upbringing of her son, to her two brothers, James and Alexander Wright, the one a saddler, the other a carpenter. Scrupulous integrity, sincere religion, unflagging industry, and resolute contentment were the lessons which these men, not so much by precept as by example, impressed upon the boy. But young Miller had inherited from his father a strong individuality and obstinate force of will, and began at a very early age to take a line of his own. The enchantment of open air and freedom—the irresistible charm of mother nature on the hill and by the sea—made him at thirteen an incorrigible truant; and his schoolmaster thought it likely that he would prove a dunce. Nevertheless the truant schoolboy was already giving indications of the destination of the man. At an age too early to date he had found in his pen a divining rod that led him to waters of inexhaustible delight. His mother summed up, in the singular dialect of the district, the impression derived from her son's boyhood and youth in the words, "he was aye vritin." But the writing from the first, and increasingly as time went on, could be discriminated from the ordinary productions of boyhood. A continuity of idea, an indefinable grace and freshness, marked his performances. They were never bombastic or verbose. At no period of his life did he suffer from a flux of words. But, boy and man, he had a felicitous knack of fitting words into their right places and avoiding jerkiness and inequality. In verse he lacked the passionate intensity required for true rhythmic movement, but he had a fine sense of cadence and modulation in prose.

It is a curious fact that what determined Hugh Miller to apprentice himself to a stone-mason was his delight in literary composition. Unemployed during the winter frosts, the mason, he perceived, could enjoy for some months every year the ecstacy of writing. One result of his decision was that he never learned any language but English. Another was that fifteen years of the quarry and the hewing-shed, with stern experiences of over-work and privation, sowed in his frame the seeds of incurable disease. Meanwhile the advantages of his decision were indisputable. Under the discipline of labour the refractory schoolboy became a thoughtful, sober-minded man. Miller always looked back to his years of hand-labour with a satisfaction that has something in it of solemnity and pathos. "Noble, upright, self-relying toil," he exclaims; "who that knows thy solid worth and value would be ashamed of thy hard hands, and thy soiled vestments, and thy obscure tasks,—thy humble cottage, and hard couch, and homely fare!"

It cannot be added that his fifteen years of close and constant intercourse with fellow-workmen inspired him with much respect for their class. He was most unfortunate in his comrades during the two seasons, 1824 and 1825, when he worked at Niddrie in the neighbourhood of Edinburgh. Swinish in their enjoyments, meanly selfish in their class ambitions, and fatuously subject to talking charlatans, that Niddrie squad of reprobates which he describes in *My Schools and Schoolmasters* stamped on the mind of Hugh Miller an indelible conviction of the incapacity and degradation of the hand-workers.

Returning to Cromarty, he worked in happy patience as a stone-cutter year after year, sedulously prosecuting at the same time the grand object of his ambition, to write good English. He found time to invigorate and enrich his mind by careful reading, and was habitually and keenly observant both of man and of nature. His reading was not extensive but well chosen, and embraced Locke and Hume; Goldsmith and Addison were, more than any others, his masters in style. It was to get time to write that he had become a stone-mason; another of the surprises of his career is that it was in advertising himself as a mason that he came before the world as a literary man. A stone-mason, figuring as a poetical contributor to the *Inverness Courier*, might, he thought, be asked by some of the readers to engrave inscriptions on tombs. He therefore forwarded some of his verses to the editor. These seem to have been consigned to the waste-paper basket, which had been the fate of an "Ode on Greece" offered to the *Scotsman* when he was at Edinburgh. Piqued by his second failure, he now resolved, at all hazards, to see himself in print. In 1829 appeared the small volume containing *Poems Written in the Leisure Hours of a Journeyman Mason*. It procured its author the valuable friendship of Mr Robert Carruthers, and was favourably noticed by the press. Miller looked at his poems in print, and concluded, at once and irreversibly, that he would not succeed as a poet. It was a characteristic and very manly decision, proving that there was no fretting vanity in his disposition. Doubtless also it was right. His field was prose. But, though his poems yielded nothing in the way of fortune, they were a beginning of fame. The simple natives of Cromarty began to think him a wonder. Some very elo-

MILLET (French, *millet*; Italian, *miglietto*, diminutive of *miglio*=Latin *mille*, a thousand, in allusion to its fertility) is a name applied with little definiteness to a considerable number of often very variable species of cereals belonging to distinct genera and even subfamilies of *Gramineæ*. The true millet, however, is generally admitted to be *Panicum* (*Setaria*) *miliaceum*, L. (German *Hirse*, with which *P. miliare*, Lam., is reckoned by some botanists). It is indigenous to the East Indies and North Australia, but is mentioned by Hippocrates and Theophrastus as already cultivated in South Europe in their time. Some suppose it to be one of the earliest grains used in bread-making, and ascribe the origin of its name to *panis*, bread, rather than to the paniculate inflorescence. It is annual, requires rich but friable soil, grows to about 3 or 4 feet high, and is characterized by its bristly, much branched nodding panicles. One variety has black grains. It is largely cultivated in India, southern Europe, and northern Africa, and ripens as far north as southern Germany, in fact, wherever the climate admits of the production of wine. The grain, which is very nutritious, is used in the form of groats, and makes excellent bread when mixed with wheaten flour. It is also largely used for feeding poultry and cage-birds, for which purpose mainly it is imported. *P. italicum*, L. (*Setaria italica*, Beauv.), is of similar origin and distribution, and is one of the most wholesome and palatable Indian cereals. It is annual, grows 4 to 5 feet high, and requires dry light soil. German Millet (*P. germanicum*, German *Kolbenhirse*, *Mohar*) is probably merely a less valuable and dwarf variety of *P. italicum*, having an erect, compact, and shorter spike. The grains of both are very small, only one half as long as those of common millet, but are exceedingly prolific. Many stalks arise from a single root, and a single spike often yields 2 oz. of grain, the total yield being five times that of wheat. They are imported for poultry feeding like the former species, but are extensively used in soups, &c., on the Continent. Numerous other species belonging to this vast genus—the largest among grasses, of which the following are among the most important—are also cultivated in tropical or sub-tropical countries for their grain or as fodder grasses, or both, each variety of soil, from swamp to desert, having its characteristic forms. They are very readily acclimatized wherever the temperature is sufficient, *e.g.*, in Australia, and seem destined to rise in agricultural importance.

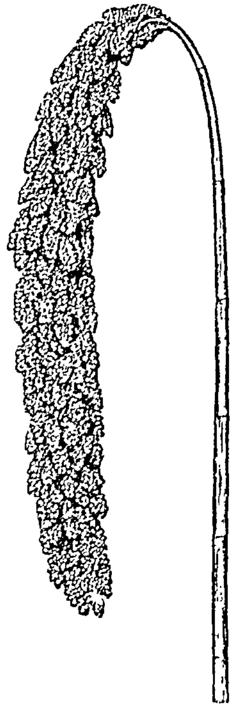


FIG. 1.—*Panicum italicum.*

Polish Millet is *P. digitaria*; *P. frumentaceum*, Roxb., Shamalo, a Deccan grass, is probably a native of tropical Africa; while the perennial *P. sarmentosum*, Roxb., also largely cultivated in tropical countries, is from Sumatra. *P. decompositum* is the Australian millet, its grains being made into cakes by the aborigines. *P. maximum*, Jacq., is the Guinea Grass; it is perennial, grows 8 feet high, and yields abundance of highly nutritious grain. *P. spectabile*, Nees., is the Coapim of Angola, but has been acclimatized in Brazil and other tropical countries. Other gigantic species 6 or 7 feet high form the field crops on the banks of the Amazons. Of species belonging to allied genera, *Pennisetum thyphoideum*, Rich. (*Penicellaria spicata*, Willd.), Bajree, sometimes also called Egyptian Millet, a Guinea corn, is largely cultivated in tropical Asia, Nubia, and Egypt. *P. distichum* grows south of the Sahara. Species of *Paspalum*, *Eleusine*, and *Milium* are also cultivated as millets.

But the most important dry grain of the tropical countries of Africa and Asia, particularly of India, is *Sorghum vulgare*, Pers. (*Holcus Sorghum*, L., *Andropogon Sorghum*, Roxb.), Durra, Great Millet, Indian Millet, Turkish Millet, or Guinea Corn (the French *sorgho*, German *Mohrenhirse* or *Kaffernkorn*, Tamil *Cholum*, Bengalese *Jowari*). It ranges probably as extensively as wheat, being also largely cultivated in southern Europe, the United States, and the West Indies. In Asia Minor, Arabia, Italy, and Spain it may be said to replace oats and barley. It is annual, and may reach 12 feet in height; it is extremely prolific, even rivalling maize, of which it is a near congener. Its flour is very white, but does not easily make good bread; it is largely used in cakes and puddings and for feeding cattle and poultry. The panicles are used for brooms, and the roots for velvet-brushes. *S. bicolor*, *S. nigrum*, *S. rubrum*, *S. Kaffrorum* (Kaffre Corn), *S. saccharatum*, and other species or varieties are also of economic importance, the last-named (the "Chinese sugar-cane") being much cultivated in the United States as a source of molasses, the juice, which contains much glucose but comparatively little cane sugar, being simply expressed and concentrated by evaporation. *S. vulgare* is the grain referred to by Pliny as millet.

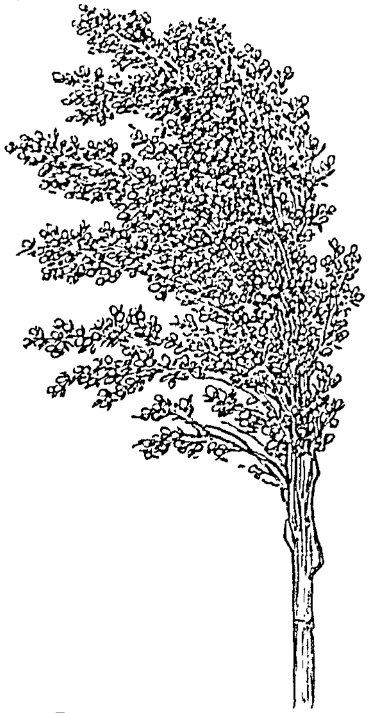


FIG. 2.—*Sorghum vulgare.*

For systematic and economic purposes, see GRASSES; Luerssen, *Med.-Pharm. Botanik*, Leipsic, 1880; Drury, *Useful Plants of India*, London, 1873; F. v. Müller, *Select Plants for Naturalization in Victoria*, Melbourne, 1876. For archæology, see Helm's *Kulturpflanzen*, &c., Berlin, 1877. On *Sorghum cerunum* ("rice corn," &c., of western Kansas) see Drummond's "Report" in *Parl. Papers*, No. 2570 (1880).

MILLET, JEAN FRANÇOIS (1814–1875), was a painter of French peasant life, and it may be questioned whether France has produced in our day any greater or more original artist. He himself came of a peasant family, and was born on the 4th of October 1814 in the hamlet of Gruchy, near Gréville (La Manche), in the wild and picturesque district called La Hague. His boyhood was passed working in his father's fields, but the sight of the engravings in an old illustrated Bible set him drawing, and thenceforth, whilst the others slept, the daily hour of rest was spent by Millet in trying to render the familiar scenes around him. From the village priest the lad learnt to read the Bible and Virgil in Latin, and acquired an interest in one or two other works of a high class which accompanied him through life; he did not, however, attract attention so much by his acquirements as by the stamp of his mind. The whole family seems, indeed, to have worn a character of austerity and dignity, and when Millet's father finally decided to test the vocation of his son as an artist, it was with a gravity and authority which recalls the patriarchal households of Calvinist France. Two drawings were prepared and placed before a painter at Cherbourg named Mouchel, who at once recognized the boy's gifts, and accepted him as a pupil; but shortly after (1835) Millet's father died, and the eldest son, with heroic devotion, took his place at home, nor did he return to his work until the

pressing calls from without were solemnly enforced by the wishes of his own family. He accordingly went back to Cherbourg, but after a short time spent there with another master (Langlois) started with many misgivings for Paris. The council-general of the department had granted him a sum of 600 francs, and the town council promised an annual pension of 400, but in spite of friendly help and introductions Millet went through great difficulties. The system of the École des Beaux Arts was hateful to him, and it was not until after much hesitation that he decided to enter an official studio—that of Delaroche. The master was certainly puzzled by his pupil; he saw his ability, and, when Millet in his poverty could not longer pay the monthly fees, arranged for his free admission to the studio, but he tried in vain to make him take the approved direction, and lessons ended with "Eh, bien, allez à votre guise, vous êtes si nouveau pour moi que je ne veux rien vous dire." At last, when the competition for the Grand Prix came on, Delaroche gave Millet to understand that he intended to secure the nomination of *another*, and thereupon Millet withdrew himself, and with his friend Marolle started in a little studio in the Rue de l'Est. He had renounced the beaten track, but he continued to study hard whilst he sought to procure bread by painting portraits at 10 or 15 francs a piece and producing small "pastiches" of Watteau and Boucher. These works are classed as those of his "flowery manner," and Millet has been reproached—he whose whole life was an act of conviction—with having sacrificed his convictions to curry favour with the public. It is true that he himself has recorded his aversion to both these masters. "In the Louvre," he said, "I received vivid impressions from Mantegna, complete from Michelangelo; after Michelangelo and Poussin I have remained faithful to the early masters." Boucher was for him an object of "repulsion," and in Watteau "I saw," he said, "a little theatrical world which oppressed me." Thus it was then that Millet naturally felt and saw, but the strongest genius knows moments of self-doubt. Later in life Millet was heard to say that were it not for the small group who believed in him he should have lost faith in himself. In earlier years, before he was certain of his own leading, he was naturally influenced by the advice of others whose arguments were enforced by the pressure of dire poverty. Even so from time to time the native vein showed strong. In 1840, as soon as he had despatched a portrait to the Salon, Millet went back to Gréville, where he painted Sailors Mending a Sail and a few other pictures—reminiscences of Cherbourg life. His first success was obtained in 1844 when his Milkwoman and Lesson in Riding (pastel) attracted notice at the Salon, and friendly artists presented themselves at his lodgings only to learn that his wife had just died, and that he himself had disappeared. Millet was at Cherbourg; there he remarried, but having amassed a few hundred francs he went back to Paris and presented his St Jerome at the Salon of 1845. This picture was rejected and exists no longer, for Millet, short of canvas, painted over it Œdipus Unbound, a work which during the following year was the object of violent criticism. He was, however, no longer alone; Diaz, Eugène Tourneux, Rousseau, and other men of note supported him by their confidence and friendship, and he had by his side the brave Catharine Lemaire, his second wife, a woman who bore poverty with dignity and gave courage to her husband through the cruel trials in which he penetrated by a terrible personal experience the bitter secrets of the very poor. To this date belong Millet's Golden Age, Bird Nesters, Young Girl and Lamb, and Bathers; but to the Bathers (Louvre) succeeded The Mother Asking Alms, The Workman's Monday, and The Winnower. This last work, exhibited in 1848, obtained conspicuous success, but did not sell till Ledru Rollin, informed of the painter's dire distress, gave him 500 francs for it, and accompanied the purchase with a commission, the money for which enabled Millet to leave Paris for Barbizon, a village on the skirts of the forest of Fontainebleau. There he settled in a three-roomed cottage for the rest of his life—twenty-seven years, in which he wrought out the perfect story of that peasant life of which he alone has given a "complete impression." Jules Breton has coloured the days of toil with sentiment; others, like Courbet, whose eccentric Funeral at Ornans attracted more notice at the Salon of 1850 than Millet's Sowers and Binders, have treated similar subjects as a vehicle for protest against social misery; Millet alone, a peasant and a miserable one himself, saw true, neither softening nor exaggerating what he saw. In a curious letter written to M. Sensier at this date (1850) Millet expressed his resolve to break once and for all with mythological and undraped subjects, and the names of the principal works painted subsequently will show how stedfastly this resolution was kept. In 1852 he produced Girls Sewing, Man Spreading Manure; 1853, The Reapers; 1854, Church at Gréville (Luxembourg); 1855—the year of the International Exhibition, at which he received a medal of second class—Peasant Grafting a Tree; 1857, The Gleaners; 1859, The Angelus (Louvre, engraved Waltner), The Woodcutter and Death; 1860, Sheep Shearing; 1861, Woman Shearing Sheep, Woman Feeding Child; 1862, Potato Planters, Winter and the Crows; 1863, Man with Hoe, Woman Carding; 1864, Shepherds and Flock, Peasants Bringing Home a Calf Born in the Fields; 1869, Knitting Lesson; 1870, Buttermaking; 1871, November—recollection of Gruchy. Any one of these works will show how great an influence Millet's previous practice in the nude had upon his style. The dresses worn by his figures are not clothes, but drapery through which the forms and movements of the body are strongly felt, and their contour shows a grand breadth of line which strikes the eye at once. Something of the imposing unity of his work was also, no doubt, due to an extraordinary power of memory, which enabled Millet to paint (like Horace Vernet) without a model; he could recall with precision the smallest details of attitudes or gestures which he proposed to represent. Thus he could count on presenting free from after thoughts the vivid impressions which he had first received, and Millet's nature was such that the impressions which he received were always of a serious and often of a noble order, to which the character of his execution responded so perfectly that even a Washerwoman at her Tub will show the grand action of a Medea. The drawing of this subject is reproduced in *Souvenirs de Barbizon*, a pamphlet in which M. Piédagnel has recorded a visit paid to Millet in 1864. His circumstances were then less evil, after struggles as severe as those endured in Paris. A contract by which he bound himself in 1860 to give up all his work for three years had placed him in possession of 1000 francs a month. His fame extended, and at the exhibition of 1867 he received a medal of the first class, and the ribbon of the Legion of Honour, but he was at the same moment deeply shaken by the death of his faithful friend Rousseau. Though he rallied for a time he never completely recovered his health, and on the 20th January 1875 he died. He was buried by his friend's side in the churchyard of Chailly.

See A. Sensier, *Vie et Œuvre de J. F. Millet*, 1874; Piédagnel, *Souvenirs de Barbizon*, &c. (E. F. S. P.)

MILLVILLE, a city of the United States, in Cumberland county, New Jersey, at the head of navigation of Maurice river, 40 miles by rail from Philadelphia by the Cape May, Millville, and Vineland section of the West Jersey Railroad.

It is one of the chief seats of glass-making in the State, and also manufactures cotton, iron pipes for water and gas, turbines, &c. The population was 7660 in 1880.

MILMAN, Henry Hart (1791–1868), dean of St Paul's, was born February 10, 1791, and was the third son of Sir Francis Milman, physician to George III. He was educated at Eton and at Brasenose College, Oxford; his university career was brilliant, and among other distinctions he gained the Newdigate prize with a poem on the Apollo Belvedere. In 1816 he was ordained, and was soon afterwards presented to the living of St Mary's, Reading. He had already made his appearance as a dramatic writer, his tragedy of *Fazio*, founded on a narrative in the *Annual Register* for 1795, having been brought on the stage without his knowledge under the title of *The Italian Wife*. It was subsequently produced at Covent Garden, and obtained great success from the acting of Miss O'Neill as Bianca. The merit of the play consists chiefly in the powerful situation; the diction is florid and ornate. The same criticism, by the author's own confession, applies to his epic, *Samor, the Lord of the Bright City* (Gloucester), a poem written in early youth. The subject is taken from British legend, and Milman has failed to invest it with serious interest. He was more successful in his next attempts, where the subjects were well adapted to an imagination easily kindled by the historical or the moral picturesque. The death struggle of an expiring nation in the *Fall of Jerusalem* (1820), the conflict of new truth and old order, of religious enthusiasm and earthly affection, in the *Martyr of Antioch* (1822), are depicted with great eloquence and real insight into human nature. Milman's characters, however, are personified tendencies rather than personages, and in poetical style he was unable to free himself from the influence of Byron. *Belshazzar* (1822) is in general a pale copy of Byron's *Sardanapalus*, but contains some fine lyrics. Milman's lyrics, indeed, especially his hymns, have frequently a fine ring and sweep, though the thought is generally commonplace. His tragedy of *Anne Boleyn* (1826) is a poor performance. With the exception of admirable versions of the Sanskrit episode of Nala and Damayanti, and of the *Agamemnon* and *Bacchæ*, this was Milman's last poetical work. He was elected professor of poetry at Oxford, and in 1827 delivered the Bampton lectures, selecting as his subject the conduct and character of the apostles as an evidence of Christianity. In 1830 his *History of the Jews* appeared in the Family Library. The contracted limits of this series forbade any adequate treatment of the subject; the work is nevertheless memorable as the first by an English clergyman which treated the Jews as an Oriental tribe, recognized sheikhs and emirs in the Old Testament, sifted and classified documentary evidence, and evaded or minimized the miraculous. Milman was violently attacked, especially by Dr Faussett and Bishop Mant, and the odium thus occasioned stopped the publication of the Family Library, and long impeded the preferment of the writer. In 1835, however, Sir Robert Peel made him rector of St Margaret's and canon of Westminster, and in 1849 he became dean of St Paul's. The unpopularity attaching to him had by this time nearly died away; and now, generally revered and beloved, intimate with men of all pursuits, politics, and persuasions, counted among the chief ornaments of the most polished society of the metropolis, he occupied a singularly dignified and enviable position, which he constantly employed for the promotion of culture and enlightenment, and in particular for the relaxation of subscription to ecclesiastical formularies. His *History of Christianity under the Empire* had appeared in 1840, but had been as completely ignored as if, said Lord Melbourne, the clergy had taken a universal oath never to mention it to any one. Widely different was the reception of the continuation, his great *History of Latin Christianity* to the death of Pope Nicholas V., which appeared in 1855. He also edited Gibbon and Horace, and at his death in 1868 left behind him almost finished a delightful history of his own cathedral, which was completed and published by his son.

Milman possessed a large share of the imagination which enters into and calls up the past, and of that which interprets actions and apprehends opinions by the power of sympathy. In creative imagination he was deficient, a defect which alone prevented him from attaining the first rank as an historian. His pages are crowded with splendid names rather than with living personages; the springs of action are disclosed with remarkable penetration, but the actor himself is rather heard than seen. There are, however, exceptions, such as his portrait of Sir Christopher Wren; and he possessed a peculiar power of investing mere intellectual tendencies with personality and life. His parallel of Latin and Teutonic Christianity, for example, is a piece of finished historical character painting. His power of sympathy rendered him in effect, as his natural equity and benignity made him in intention, a model of historical candour, only chargeable, perhaps, with too much gentleness. It will be long ere his great work is superseded; but he will perhaps be remembered even longer as an embodiment of all the qualities which the higher ecclesiastical preferment can be supposed capable of encouraging or rewarding among the clergy of a great historical church. (R. G.)

MILO, one of the most famous athletes of Greece, whose name became proverbial for personal strength. He lived about the end of the 6th century B.C., was six times crowned at the Olympic games and six times at the Pythian for wrestling, and was famous throughout the civilized world for his feats of strength, such as carrying an ox on his shoulders through the stadium at Olympia. In his native city of Crotona he was much honoured, and he commanded the army which defeated the people of Sybaris in 511 B.C. When Democedes, the physician of Darius, deserted the Persian service, he sent a boastful message to the king of Persia informing him of his marriage to the daughter of Milo. The traditional account of his death is often used to point a moral: he found a tree which some woodcutters had partially split with a wedge, and attempted to rend it asunder; but the wedge fell out, and the tree closed on his hand, imprisoning him till wolves came and devoured him.

MILO was the surname of T. Annius Papianus, one of the best-known of the partisan leaders and ruffians in the stormy times that preceded the dissolution of the Roman republic. His father was C. Papius Celsus, but he was adopted by his mother's father T. Annius Luscus. He joined the Pompeian party, and led the band of mercenaries and gladiators which was required to defend the cause and its chief supporters in the public streets. P. Clodius, the leader of the ruffians who professed the democratic cause, was his personal enemy, and their brawls in the streets and their mutual accusations in the law courts lasted for several years, beginning when Milo was tribune of the commons in 57 B.C. In 53 their quarrels came to a height when Milo was candidate for the consulship and Clodius for the prætorship; and when the two leaders met by accident on the Appian Way at Bovillæ, Clodius was murdered (January 20, 52 B.C.). This act of violence strengthened the hands of Pompey, who was nominated sole consul, and proposed several stringent laws to restore order in the city. Milo was impeached; his guilt was clear, and his enemies took every means of intimidating his supporters and his judges. Cicero was afraid to deliver the speech he had prepared *Pro Milone*, and the extant oration is an expanded form of the unspoken defence. Milo went into exile at Massilia, and his property was sold by auction. He joined the insurrection of M. Cælius in 48 B.C., and was soon slain near Thurii in Lucania. His wife Fausta was daughter of the dictator Sulla.

MILTIADES. See Greece, vol. xi. p. 99.

MILTON, JOHN (1608–1674), was born in Bread Street, Cheapside, London, on the 9th of December 1608. His father, known as Mr John Milton of Bread Street, scrivener, was himself an interesting man. He was a native of Oxfordshire, having been born there in or about 1563, the son of a Richard Milton, yeoman of Stanton-St-John's, of whom there are traces as one of the sturdiest adherents to the old Roman Catholic religion that had been left in his district. The son, however, had turned Protestant, and, having been cast off on that account, had come to London, apparently about the year 1586, to push his fortune. Having received a good education, and having good abilities, especially in music, he may have lived for some time by musical teaching and practice. Not till 1595, at all events, when he was long past the usual age of apprenticeship, do we hear of his preparation for the profession of a scrivener; and not till February 1599–1600, when he was about thirty-seven years of age, did he enter the profession as a qualified member of the Scriveners' Company. It was then that he set up his "house and shop" in Bread Street, and began, like other scriveners, his lawyerly business of drawing up wills, marriage-settlements, and the like, with such related business as that of receiving money from clients for investment and lending it out to the best advantage. It was at the same time that he married. Till recently there has been the most extraordinary uncertainty as to the maiden name of his wife, the mother of the poet. It has been now ascertained, however, that she was a Sarah Jeffrey, one of the two orphan daughters of a Paul Jeffrey, of St Swithin's, London, "citizen and merchant-taylor," originally from Essex, who had died before 1583. At the date of her marriage she was about twenty-eight years of age. Her widowed mother, Mrs Ellen Jeffrey, came to reside in the house in Bread Street, and died there in February 1610–11. Before this death of the maternal grandmother, three children had been born to the scrivener and his wife, of whom only two survived,—the future poet, and an elder sister, called Anne. Of three more children, born subsequently, only one survived,—Christopher, the youngest of the family, born December 3, 1615.

The first sixteen years of Milton's life, coinciding exactly with the last sixteen of the reign of James I., associate themselves with the house in Bread Street, and with the surroundings of that house in Old London. His father, while prospering in business, continued to be known as a man of "ingeniose" tastes, and even acquired some distinction in the London musical world of that time by his occasional contributions to important musical publications. Music was thus a part of the poet's domestic education from his infancy. Whatever else could be added was added without stint. Again and again Milton speaks with gratitude and affection of the ungrudging pains bestowed by his father on his early education. "Both at the grammar school and also under other masters at home," is the statement in one passage, "he caused me to be instructed daily." This brings us to about the year 1619, when Milton was ten years of age. At that time his domestic tutor was Thomas Young, a Scotsman from Perthshire, and graduate of the university of St Andrews, afterwards a man of no small distinction among the English Puritan clergy, but then only curate or assistant to some parish clergyman in or near London, and eking out his livelihood by private teaching. Young's tutorship lasted till 1622, when he was drawn abroad by an offer of the pastorship or chaplaincy to the congregation of English merchants in Hamburg. Already, however, for a year or two, his tutorship had been only supplementary to the education which the boy was receiving by daily attendance at St Paul's public school, close to Bread Street. The headmaster of the school was Mr Alexander Gill, an elderly Oxford divine, of high reputation for scholarship and teaching ability. Under him, as usher or second master, was his son, Alexander Gill the younger, also an Oxford graduate of scholarly reputation, but of blustering character. Milton's acquaintanceship with this younger Gill, begun at St Paul's school, led to subsequent friendship and correspondence. Far more affectionate and intimate was the friendship formed by Milton at St Paul's with a certain young Charles Diodati, his schoolfellow there, the son of a naturalized Italian physician, Dr Theodore Diodati, who had settled in London in good medical practice, and was much respected, both on his own account, and as being the brother of the famous Protestant divine, Jean or Giovanni Diodati of Geneva. Young Diodati, who was destined for his father's profession, left the school for Oxford University early in 1623; but Milton remained till the end of 1624. A family incident of that year was the marriage of his elder sister, Anne, with Edward Phillips, a clerk in the Government office called the Crown Office in Chancery. Milton had then all but completed his sixteenth year, and was as scholarly, as accomplished, and as handsome a youth as St Paul's school had sent forth. We learn from himself that his exercises "in English or other tongue, prosing or versing, but chiefly this latter," had begun to attract attention even in his boyhood. This implies that he must have had a stock of attempts in English and Latin by him of earlier date than 1624. Of these the only specimens that now remain are his *Paraphrase on Psalm CXIV.* and his *Paraphrase on Psalm CXXXVI.*

On February 12, 1624–25, Milton, at the age of sixteen years and two months, was entered as a student of Christ's College, Cambridge, in the grade of a "Lesser Pensioner." His matriculation entry in the books of the university is two months later, April 9, 1625. Between these two dates James I. had died, and had been succeeded by Charles I.

Cambridge University was then in the full flush of its prosperity on that old system of university education which combined Latin and Greek studies with plentiful drill and disputation in the scholastic logic and philosophy, but with little of physical science, and next to no mathematics. There were sixteen colleges in all, dividing among them a total of about 2900 members of the university. Christ's College, to which Milton belonged, ranked about third in the university in respect of numbers, counting about 265 members on its books. The master was Dr Thomas Bainbrigge; and among the thirteen fellows were Mr Joseph Meade, still remembered as a commentator on the Apocalypse, and Mr William Chappell, afterwards an Irish bishop. It was under Chappell's tutorship that Milton was placed when he first entered the college. At least three students who entered Christ's after Milton, but during his residence, deserve mention. One was Edward King, a youth of Irish birth and high Irish connexions, who entered in 1626, at the age of fourteen; another was John Cleveland, afterwards known as royalist and satirist, who entered in 1627; and the third was Henry More, subsequently famous as the Cambridge Platonist, who entered in 1631, just before Milton left. Milton's own brother, Christopher, joined him in the college in February 1630–31, at the age of fifteen.

Milton's academic course lasted seven years and five months, or from February 1624–25 to July 1632, bringing him from his seventeenth year to his twenty-fourth. The first four years were his time of undergraduateship. It was in the second of these, the year 1626, that there occurred that quarrel between him and his tutor, Mr Chappell, which Dr Johnson, making the most of a lax tradition from Aubrey, magnified into the supposition that Milton may have been one of the last students in either of the English universities that suffered the indignity of

went through, he tells us, a systematic course of reading in the Greek and Latin classics, varied by mathematics, music, and the kind of physical science we should now call cosmography.

It is an interesting fact that Milton's very first public appearance in the world of English authorship was in so honourable a place as the second folio edition of *Shakespeare* in 1632. His enthusiastic eulogy on Shakespeare, written in 1630, was one of three anonymous pieces prefixed to that second folio, along with reprints of the commendatory verses that had appeared in the first folio, one of them Ben Jonson's immortal tribute to Shakespeare's memory. Among the poems actually written by Milton at Horton the first, in all probability, after the Latin hexameters *Ad Patrem*, were the exquisite companion pieces *L'Allegro* and *Il Penseroso.* There followed, in or about 1633, the fragment called *Arcades.* It was part of a pastoral masque got up by the young people of the noble family of Egerton in honour of their venerable relative the countess-dowager of Derby, and performed before that lady at her mansion of Harefield, near Uxbridge, about 10 miles from Horton. That Milton contributed the words for the entertainment was, almost certainly, owing to his friendship with Henry Lawes, one of the chief court musicians of that time, whose known connexion with the Egerton family points him out as the probable manager of the Harefield masque. Next in order among the compositions at Horton may be mentioned the three short pieces, *At a Solemn Music*, *On Time*, and *Upon the Circumcision*; after which comes *Comus*, the largest and most important of all Milton's minor poems. The name by which that beautiful drama is now universally known was not given to it by Milton himself. He entitled it, more simply and vaguely, "A Masque presented at Ludlow Castle, 1634, before the Earl of Bridgewater, Lord President of Wales." The existence of this poem is certainly due to Milton's intimacy with Lawes. The earl of Bridgewater, the head of the Egerton family, had been appointed to the high office of the presidency or viceroyalty of Wales, the official seat of which was Ludlow in Shropshire; it had been determined that among the festivities on his assumption of the office there should be a great masque in the hall of Ludlow Castle, with Lawes for the stage manager and one of the actors; Milton had been applied to by Lawes for the poetry; and, actually, on Michaelmas night, September 29, 1634, the drama furnished by Milton was performed in Ludlow Castle before a great assemblage of the nobility and gentry of the Welsh principality, Lawes taking the part of "the attendant spirit," while the parts of "first brother," "second brother," and "the lady" were taken by the earl's three youngest children, Viscount Brackley, Mr Thomas Egerton, and Lady Alice Egerton.—From September 1634 to the beginning of 1637 is a comparative blank in our records. Straggling incidents in this blank are a Latin letter of date December 4, 1634, to Alexander Gill the younger, a *Greek Translation of Psalm CXIV.*, a visit to Oxford in 1635 for the purpose of incorporation in the degree of M.A. in that university, and the beginning in May 1636 of a troublesome lawsuit against his now aged and infirm father.—The lawsuit, which was instituted by a certain Sir Thomas Cotton, baronet, nephew and executor of a deceased John Cotton, Esq., accused the elder Milton and his partner Bower, or both, of having, in their capacity as scriveners, misappropriated divers large sums of money that had been entrusted to them by the deceased Cotton to be let out at interest. The lawsuit was still in progress when, on the 3d of April 1637, Milton's mother died, at the age of about sixty-five. A flat blue stone, with a brief inscription, visible on the chancel-pavement of Horton church, still marks the place of her burial. Milton's testimony to her character is that she was a "a most excellent mother and particularly known for her charities through the neighbourhood." The year 1637 was otherwise eventful in his biography. It was in that year that his *Comus*, after lying in manuscript for more than two years, was published by itself, in the form of a small quarto of thirty-five pages. The author's name was withheld, and the entire responsibility of the publication was assumed by Henry Lawes. Milton seems to have been in London when the little volume appeared. He was a good deal in London, at all events, during the summer and autumn months immediately following his mother's death. The plague, which had been on one of its periodical visits of ravage through England since early in the preceding year, was then especially severe in the Horton neighbourhood, while London was comparatively free. It was probably in London that Milton heard of the death of young Edward King of Christ's College, whom he had left as one of the most popular of the fellows of the college, and one of the clerical hopes of the university. King had sailed from Chester for a vacation visit to his relatives in Ireland, when, on the 10th of August, the ship, in perfectly calm water, struck on a rock and went down, he and nearly all the other passengers going down with her. There is no mention of the sad accident in two otherwise very interesting Latin *Familiar Epistles* of Milton, of September 1637, both addressed to his medical friend Charles Diodati, and both dated from London; but how deeply the death of King had affected him appears from his occupation shortly afterwards. In November 1637, and probably at Horton, whence the plague had by that time vanished, he wrote his matchless pastoral monody of *Lycidas.* It was his contribution to a collection of obituary verses, Greek, Latin, and English, which King's numerous friends, at Cambridge and elsewhere, were getting up in lamentation for his sad fate. The collection did not appear till early in 1638, when it was published in two parts, with black-bordered title-pages, from the Cambridge University press, one consisting of twenty-three Latin and Greek pieces, the other of thirteen English pieces, the last of which was Milton's monody, signed only with his initials "J. M." It was therefore early in 1638, when Milton was in his thirtieth year, that copies of his *Lycidas* may have been in circulation among those who had already become acquainted with his *Comus.*

Milton was then on the wing for a foreign tour. He had long set his heart on a visit to Italy, and circumstances now favoured his wish. The vexatious Cotton lawsuit, after hanging on for nearly two years, was at an end, as far as the elder Milton was concerned, with the most absolute and honourable vindication of his character for probity, though with some continuation of the case against his partner, Bower. Moreover, Milton's younger brother, Christopher, though but twenty-two years of age, and just about to be called to the bar of the Inner Temple, had married a wife; and the young couple had gone to reside at Horton to keep the old man company. There being nothing then to detain Milton, all was arranged for his journey. Before the end of April 1638 he was on his way across the Channel, taking one English man-servant with him. At the time of his departure the last great news in England was that of the National Scottish Covenant, or solemn oath and band of all ranks and classes of the Scottish people to stand by each other to the death in resisting the ecclesiastical innovations which Laud and Charles had been forcing upon Scotland. To Charles the news of this "damnable Covenant," as he called it, was enraging beyond measure; but to the mass of the English Puritans it was far from unwelcome, promising, as it seemed to do, for England herself, the subversion at last of that system of "Thorough," or despotic

government by the king and his ministers without parliaments, under which the country had been groaning since the contemptuous dissolution of Charles's third parliament ten years before.

Through Paris, where Milton made but a short stay, receiving polite attention from the English ambassador, Lord Scudamore, and having the honour of an introduction to the famous Hugo Grotius, then ambassador for Sweden at the French court, he moved on rapidly to Italy, by way of Nice. After visiting Genoa, Leghorn, and Pisa, he arrived at Florence, August 1638. Enchanted by the city and its society, he remained there two months, frequenting the chief academies or literary clubs, and even taking part in their proceedings. Among the Florentines with whom he became intimate were Jacopo Gaddi, young Carlo Dati, Pietro Frescobaldi, Agostino Coltellini, the grammarian Benedetto Buommattei, Valerio Chimentelli, and Antonio Francini. It was in the neighbourhood of Florence also that he "found and visited" the great Galileo, then old and blind, and still nominally a prisoner to the Inquisition for his astronomical heresy. From Florence, by Siena, Milton went to Rome. He reached the Eternal City some time in October, and spent about another two months there, not only going about among the ruins and antiquities and visiting the galleries, but mixing also, as he had done in Florence, with the learned society of the academies. Among those with whom he formed acquaintance in Rome were the German scholar, Lucas Holstenius, librarian of the Vatican, and three native Italian scholars, named Cherubini, Salzilli, and Selvaggi. There is record of his having dined once, in company with several other Englishmen, at the hospitable table of the English Jesuit College. The most picturesque incident, however, of his stay in Rome was his presence at a great musical entertainment in the palace of Cardinal Francesco Barberini. Here he had not only the honour of a specially kind reception by the cardinal himself, but also, it would appear, the supreme pleasure of listening to the marvellous Leonora Baroni, the most renowned singer of her age. Late in November he left Rome for Naples. Here also he was fortunate. The great man of the place was the now very aged Giovanni Battista Manso, marquis of Villa, the friend and biographer of the great Tasso, and subsequently the friend and patron of the sweet Marini. By a happy accident Milton obtained an introduction to Manso, and nothing could exceed the courtesy of the attentions paid by the aged marquis to the young English stranger. He had hardly been in Naples a month, however, when there came news from England which not only stopped an intention he had formed of extending his tour to Sicily and thence into Greece, but urged his immediate return home. "The sad news of civil war in England," he says, "called me back; for I considered it base that, while my fellow-countrymen were fighting at home for liberty, I should be travelling abroad for intellectual culture." In December 1638, therefore, he set his face northwards again. His return journey, however, probably because he learnt that the news he had first received was exaggerated or premature, was broken into stages. He spent a second two months in Rome, ascertained to have been January and February 1638–39; during which two months, as he tells us, he was in some danger from the papal police, because the English Jesuits in Rome had taken offence at his habit of free speech, wherever he went, on the subject of religion. Though he did not alter his demeanour in the least in this particular, nothing happened; and from Rome he got safely to Florence, welcomed back heartily by his Florentine friends, and renewing his meetings with them privately and in their academies. His second visit to Florence, including an excursion to Lucca, extended over two months; and not till April 1639 did he take his leave, and proceed, by Bologna and Ferrara, to Venice. About a month was given to Venice; and thence, having shipped for England the books he had collected in Italy, he went on, by Verona and Milan, over the Alps, to Geneva. In this Protestant city he spent a week or two in June, forming interesting acquaintanceships there too, and having daily conversations with the great Protestant theologian Dr Jean Diodati, the uncle of his friend Charles Diodati. From Geneva he returned to Paris, and so to England. He was home again in August 1639, having been absent in all fifteen or sixteen months.

Milton's Continental tour, and especially the Italian portion of it, remained one of the chief pleasures of his memory through all his subsequent life. Nor was it quite without fruits of a literary kind. Besides two of his Latin *Epistolæ Familiares*, one to the Florentine grammarian Buommattei, and the other to Lucas Holstenius, there have to be assigned to Milton's sixteen months on the Continent his three Latin epigrams *Ad Leonoram Romæ Canentem*, his Latin scazons *Ad Salsillum Poetam Romanum Ægrotantem*, his fine and valuable poem in Latin hexameters entitled *Mansus*, and his *Five Italian Sonnets, with a Canzone*, celebrating the charms of some Italian lady he had met in his travels.

One sad and marring memory did mingle itself with all that was otherwise so delightful in his Italian reminiscences. His bosom friend and companion from boyhood, the half-Italian Charles Diodati, who had been to him as Jonathan to David, and into whose ear he had hoped to pour the whole narrative of what he had seen and done abroad, had died during his absence. He had died, in Blackfriars, London, in August 1638, not four months after Milton had gone away on his tour. The intelligence had not reached Milton till some months afterwards, probably not till his second stay in Florence; and, though he must have learnt some of the particulars from the youth's uncle in Geneva, he did not know them fully till his return to England. How profoundly they affected him appears from his *Epitaphium Damonis*, then written in memory of his dead friend. The importance of this poem in Milton's biography cannot be overrated. It is perhaps the noblest of all his Latin poems; and, though in the form of a pastoral, and even of a pastoral of the most artificial sort, it is unmistakably an outburst of the most passionate personal grief. In this respect *Lycidas*, artistically perfect though that poem is, cannot be compared with it; and it is only the fact that *Lycidas* is in English, while the *Epitaphium Damonis* is in Latin, that has led to the notion that Edward King of Christ's College was peculiarly and pre-eminently the friend of Milton in his youth and early manhood.

That Milton, now in his thirty-first year, had been girding himself for some greater achievement in poetry than any he had yet attempted, *Comus* not excepted, we should have known otherwise. What we should not have known, but for an incidental passage in the *Epitaphium Damonis*, is that, at the time of his return from Italy, he had chosen a subject for such a high literary effort of a new Miltonic sort. The passage is one in which, after referring to the hopes of Diodati's medical career as so suddenly cut short by his death, Milton speaks of himself as the survivor and of his own projects in *his* profession of literature. In translation, it may run thus:—

"I have a theme of the Trojans cruising our southern headlands
Shaping to song, and the realm of Imogen, daughter of Pandras,
Brennus and Arviragh, dukes, and Bren's bold brother, Belinus;
Then the Armorican settlers under the laws of the Britons,
Ay, and the womb of Igraine fatally pregnant with Arthur,
Uther's son, whom he got disguised in Gorlois' likeness,
All by Merlin's craft. O then, if life shall be spared me,
Thou shalt be hung, my pipe, far off on some dying old pine-tree,

Much-forgotten of me; or else your Latian music
Changed for the British war-screech! What then? For one to do all things,
One to hope all things, fits not! Prize sufficiently ample
Mine, and distinction great (unheard-of ever thereafter
Though I should be and inglorious all through the world of the stranger),
If but the yellow-haired Ouse shall read me, the drinker of Alan,
Humber, which whirls as it flows, and Trent's whole valley of orchards,
Thames, my own Thames, above all, and Tamar's western waters,
Tawny with ores, and where the white waves swinge the far Orkneys."

Interpreted prosaically, this means that Milton was meditating an epic of which King Arthur was to be the central figure, but which should include somehow the whole cycle of British and Arthurian legend, and that not only was this epic to be in English, but he had resolved that all his poetry for the future should be in the same tongue.

Not long after Milton's return the house at Horton ceased to be the family home. Christopher Milton and his wife went to reside at Reading, taking the old gentleman with them, while Milton himself preferred London. He had first taken lodgings in St Bride's Churchyard, at the foot of Fleet Street; but, after a while, probably early in 1640, he removed to a "pretty garden house" of his own, at the end of an entry, in the part of Aldersgate Street which lies immediately on the city side of what is now Maidenhead Court. His sister, whose first husband had died in 1631, had married a Mr Thomas Agar, his successor in the Crown Office; and it was arranged that her two sons by her first husband should be educated by their uncle. John Phillips, the younger of them, only nine years old, had boarded with him in the St Bride's Churchyard lodgings; and, after the removal to Aldersgate Street, the other brother, Edward Phillips, only a year older, became his boarder also. Gradually a few other boys, the sons of well-to-do personal friends, joined the two Phillipses, whether as boarders or for daily lessons, so that the house in Aldersgate Street became a small private school. The drudgery of teaching seems always to have been liked by Milton. What meanwhile of the great Arthurian epic? That project, we find, had been given up, and Milton's mind was roving among many other subjects, and balancing their capabilities. How he wavered between Biblical subjects and heroic subjects from British history, and how many of each kind suggested themselves to him, one learns from a list in his own handwriting among the Milton MSS. at Cambridge. It contains jottings of no fewer than fifty-three subjects from the Old Testament, eight from the Gospels, thirty-three from British and English history before the Conquest, and five from Scottish history. It is curious that all or most of them are headed or described as subjects for "tragedies," as if the epic form had now been abandoned for the dramatic. It is more interesting still to observe which of the subjects fascinated Milton most. Though several of them are sketched pretty fully, not one is sketched at such length and so particularly as *Paradise Lost*. It is the first subject on the list, and there are four separate drafts of a possible tragedy under that title, two of them merely enumerating the *dramatis personæ*, but the last two indicating the plot and the division into acts. Thus, in 1640, twenty-seven years before *Paradise Lost* was given to the world, he had put down the name on paper, and had committed himself to the theme.

To these poetic dreamings and schemings there was to be a long interruption. The Scottish National Covenant had led to extraordinary results. Not only were Charles and Laud checkmated in their design of converting the mild Episcopal system which King James had established in Scotland into a high Laudian prelacy; but, in a General Assembly held at Glasgow in the end of 1638, Episcopacy had been utterly abolished in Scotland, and the old Presbyterian system of Knox and Melville revived. To avenge this, and restore the Scottish bishops, Charles had marched to the Border with an English army; but, met there by the Covenanting army under General Alexander Leslie, he had not deemed it prudent to risk a battle, and had yielded to a negotiation conceding to the Scots all their demands. This "First Bishops' War," as it came to be called, was begun and concluded while Milton was abroad. About the time of his return, however, Charles had again broken with the Scots. Milton had been watching the course of affairs since then with close and eager interest. He had seen and partaken in the sympathetic stir in favour of the Scots which ran through the popular and Puritan mind of England. He had welcomed the practical proof of this sympathy given in that English parliament of April 1640, called "The Short Parliament," which Charles, in his straits for supplies against the Scots, had reluctantly summoned at last, but was obliged to dismiss as unmanageable. Charles had, nevertheless, with money raised somehow, entered on the "Second Bishops' War." This time the result was momentous indeed. The Scots, not waiting to be attacked in their own country, took the aggressive, and invaded England. In August 1640, after one small engagement with a portion of Charles's army, they were in possession of Newcastle and of all the northern English counties. The English then had their opportunity. A treaty with the Scots was begun, which the English Puritans, who regarded their presence in England as the very blessing they had been praying for, were in no haste to finish; and, on the 3d of November 1640, there met that parliament which was to be famous in English history, and in the history of the world, as "The Long Parliament."

Of the first proceedings of this parliament, including the trial and execution of Strafford, the impeachment and imprisonment of Laud and others, and the break-down of the system of Thorough by miscellaneous reforms and by guarantees for parliamentary liberty, Milton was only a spectator. It was when the church question emerged distinctly as the question paramount, and there had arisen divisions on that question among those who had been practically unanimous in matters of civil reform, that he plunged in as an active adviser. There were three parties on the church question. There was a high-church party, contending for Episcopacy by divine right, and for the maintenance of English Episcopacy very much as it was; there was a middle party, defending Episcopacy on grounds of usage and expediency, but desiring to see the powers of bishops greatly curtailed, and a limited Episcopacy, with councils of presbyters round each bishop, substituted for the existing high Episcopacy; and there was the root-and-branch party, as it called itself, desiring the entire abolition of Episcopacy and the reconstruction of the English Church on something like the Scottish Presbyterian model. Since the opening of the parliament there had been a storm of pamphlets crossing one another in the air from these three parties. The chief manifesto of the high-church party was a pamphlet by Joseph Hall, bishop of Exeter, entitled *Humble Remonstrance to the High Court of Parliament*. In answer to Hall, and in representation of the views of the root-and-branch party, there had stepped forth, in March 1640–41, five leading Puritan parish ministers, the initials of whose names, clubbed together on the title-page of their joint production, made the uncouth word "Smectymnuus." These were Stephen Marshall, Edmund Calamy, Thomas Young, Matthew Newcomen, and William Spurstow. The Thomas Young whose name

comes in the middle was no other than the Scottish Thomas Young who had been Milton's domestic preceptor in Bread Street. Having returned from Hamburg in 1628, he had been appointed to the vicarage of Stowmarket in Suffolk, in which living he had remained ever since, with the reputation of being one of the most solid and learned Puritans among the English parish clergy. The famous Smectymnuan pamphlet in reply to Hall was mainly Young's. What is more interesting is that his old pupil Milton was secretly in partnership with him and his brother-Smectymnuans. Milton's hand is discernible in a portion of the original Smectymnuan pamphlet; and he continued to aid the Smectymnuans in their subsequent rejoinders to Hall's defences of himself. It was more in Milton's way, however, to appear in print independently; and in May 1641, while the controversy between Hall and the Smectymnuans was going on, he put forth a pamphlet of his own. It was entitled *Of Reformation touching Church Discipline in England and the Causes that have hitherto hindered it*, and consisted of a review of English ecclesiastical history, with an appeal to his countrymen to resume that course of reformation which he considered to have been prematurely stopped in the preceding century, and to sweep away the last relics of papacy and prelacy. Among all the root-and-branch pamphlets of the time it stood out, and stands out still, as the most thorough-going and tremendous. It was followed by four others in rapid succession,—to wit, *Of Prelatical Episcopacy and whether it may be deduced from the Apostolical Times* (June 1641), *Animadversions upon the Remonstrant's Defence against Smectymnuus* (July 1641), *The Reason of Church Government urged against Prelaty* (February 1641–42), *Apology against a Pamphlet called a Modest Confutation of the Animadversions*, &c. (March 1641–42). The first of these was directed chiefly against that middle party which advocated a limited Episcopacy, with especial reply to the arguments of Archbishop Ussher, as the chief exponent of the views of that party. Two of the others, as the titles imply, belong to the Smectymnuan series, and were castigations of Bishop Hall. The greatest of the four, and the most important of all Milton's anti-Episcopal pamphlets after the first, is that entitled *The Reason of Church Government.* It is there that Milton takes his readers into his confidence, speaking at length of himself and his motives in becoming a controversialist. Poetry, he declares, was his real vocation; it was with reluctance that he had resolved to "leave a calm and pleasing solitariness, fed with cheerful and confident thoughts, to embark in a troubled sea of noises and hoarse disputes"; but duty had left him no option. The great poem or poems he had been meditating could wait; and meanwhile, though in prose-polemics he had the use only of his "left hand," that hand should be used with all its might in the cause of his country and of liberty.

The parliament had advanced in the root-and-branch direction so far as to have passed a bill for the exclusion of bishops from the House of Lords, and compelled the king's assent to that bill, when, in August 1642, the further struggle between Charles and his subjects took the form of civil war. All England was then divided into the Royalists, supporting the king, and the Parliamentarians, adhering to that majority of the Commons, with a minority of the Lords, which sat on as the parliament. While the first battles of the civil war were being fought with varying success, this parliament, less impeded than when it had been full, moved on more and more rapidly in the root-and-branch direction, till, by midsummer 1643, the abolition of Episcopacy had been decreed, and the question of the future non-prelatic constitution of the Church of England referred to a synod of divines, to meet at Westminster under parliamentary authority. Of Milton's life through those first months of the civil war little is known. He remained in his house in Aldersgate Street, teaching his nephews and other pupils; and the only scrap that came from his pen was the semi-jocose sonnet bearing the title *When the Assault was intended to the City.* In the summer of 1643, however, there was a great change in the Aldersgate Street household. About the end of May, as his nephew Edward Phillips remembered, Milton went away on a country journey, without saying whither or for what purpose; and, when he returned, about a month afterwards, it was with a young wife, and with some of her sisters and other relatives in her company. He had, in fact, been in the very headquarters of the king and the Royalist army in and round Oxford; and the bride he brought back with him was a Mary Powell, the eldest daughter of Richard Powell, Esq., of Forest Hill, near Oxford. She was the third of a family of eleven sons and daughters, of good standing, but in rather embarrassed circumstances, and was seventeen years and four months old, while Milton was in his thirty-fifth year. However the marriage came about, it was a most unfortunate event. The Powell family were strongly Royalist, and the girl herself seems to have been frivolous, unsuitable, and stupid. Hardly were the honeymoon festivities over in Aldersgate Street when, her sisters and other relatives having returned to Forest Hill and left her alone with her husband, she pined for home again and begged to be allowed to go back on a visit. Milton consented, on the understanding that the visit was to be a brief one. This seems to have been in July 1643. Soon, however, the intimation from Forest Hill was that he need not look ever to have his wife in his house again. The resolution seems to have been mainly the girl's own, abetted by her mother; but, as the king's cause was then prospering in the field, it is a fair conjecture that the whole of the Powell family had repented of their sudden connexion with so prominent a Parliamentarian and assailant of the Church of England as Milton. While his wife was away, his old father, who had been residing for three years with his younger and lawyer son at Reading, came to take up his quarters in Aldersgate Street.

Milton's conduct under the insult of his wife's desertion was most characteristic. Always fearless and speculative, he converted his own case into a public protest against the existing law and theory of marriage. *The Doctrine and Discipline of Divorce Restored, to the good of both Sexes*, was the title of a pamphlet put forth by him in August 1643, without his name, but with no effort at concealment, declaring the notion of a sacramental sanctity in the marriage relation to be a clerically invented superstition, and arguing that inherent incompatibility of character, or contrariety of mind, between two married persons, is a perfectly just reason for divorce. There was no reference to his own case, except by implication; but the boldness of the speculation roused attention and sent a shock through London. It was a time when the authors of heresies of this sort, or of any sort, ran considerable risks. The famous Westminster Assembly of Divines, called by the Long Parliament, had met on the appointed day, July 1, 1643; the Scots, in consenting to send an army into England to assist the parliament in their war with the king, had proposed, as one of the conditions, their Solemn League and Covenant, binding the two nations to endeavour after a uniformity of religion and of ecclesiastical discipline, with the extirpation of all "heresy, schism, and profaneness," as well as popery and prelacy; the Solemn League and Covenant had been enthusiastically accepted in England, and was being sworn to universally by the Parliamentarians; and one immediate effect was that four eminent Scottish

divines and two Scottish lay commissioners were added to the Westminster Assembly and became leaders there. Whether Milton's divorce tract was formally discussed in the Assembly during the first months of its sitting is unknown; but it is certain that the London clergy, including not a few members of the Assembly, were then talking about it privately with anger and execration. That there might be no obstacle to a more public prosecution, Milton threw off the anonymous in a second and much enlarged edition of the tract, in February 1643–44, dedicated openly to the parliament and the Assembly. Then, for a month or two, during which the gossip about him and his monstrous doctrine was spreading more and more, he turned his attention to other subjects. Among the questions in agitation in the general ferment of opinion brought about by the civil war was that of a reform of the national system of education and especially of the universities. To this question Milton made a contribution in June 1644, in a small *Tract on Education*, in the form of a letter to Mr Samuel Hartlib, a German then resident in London and interesting himself busily in all philanthropic projects and schemes of social reform. In the very next month, however, July 1644, he returned to the divorce subject in a pamphlet addressed specially to the clergy and entitled *The Judgment of Martin Bucer concerning Divorce.* The outcry against him then reached its height. He was attacked in pamphlets; he was denounced in pulpits all through London, and more than once in sermons before the two Houses of Parliament by prominent divines of the Westminster Assembly; strenuous efforts were made to bring him within definite parliamentary censure. In the cabal formed against him for this purpose a leading part was played, at the instigation of the clergy, by the Stationers' Company of London. That company, representing the publishers and booksellers of London, had a plea of their own against him, on the ground that his doctrine was not only immoral, but had been put forth in an illegal manner. His first divorce treatise, though published immediately after the "Printing Ordinance" of the parliament of June 14, 1643, requiring all publications to be licensed for press by one of the official censors, and to be registered in the books of the Stationers' Company, had been issued without licence and without registration. Complaint to this effect was made against Milton, with some others liable to the same charge of contempt of the printing ordinance, in a petition of the Stationers to the House of Commons in August 1644; and the matter came before committee both in that House and in the Lords. It is to this circumstance that the world owes the most popular and eloquent, if not the greatest, of all Milton's prose-writings, his famous *Areopagitica, a Speech of Mr John Milton for the Liberty of Unlicensed Printing to the Parliament of England.* It appeared in the end of November 1644, deliberately unlicensed and unregistered, as was proper on such an occasion, and was a remonstrance addressed to the parliament, as if in an oration to them face to face, against their ordinance of June 1643 and the whole system of licensing and censorship of the press. Nobly eulogistic of the parliament in other respects, it denounced their printing ordinance as utterly unworthy of them, and of the new era of English liberties which they were initiating, and called for its repeal. Though that effect did not follow, the pamphlet virtually accomplished its purpose. The licensing system had received its death-blow; and, though the Stationers returned to the charge in another complaint to the House of Lords, Milton's offence against the press ordinance was condoned. He was still assailed in pamphlets, and found himself "in a world of disesteem"; but he lived on through the winter of 1644–45 undisturbed in his house in Aldersgate Street. To this period there belong, in the shape of verse, only his sonnets ix. and x., the first to some anonymous lady, and the second "to the Lady Margaret Ley," with perhaps the Greek lines entitled *Philosophus ad Regem Quendam.* His divorce speculation, however, still occupied him; and in March 1644–45 he published simultaneously his *Tetrachordon, or Expositions upon the four chief places of Scripture which treat of Marriage,* and his *Colasterion, a Reply to a nameless Answer against the Doctrine and Discipline of Divorce.* In these he replied to his chief recent assailants, lay and clerical, with merciless severity.

It was not merely Milton's intellectual eminence that had saved him from prosecution for his divorce heresy. A new tendency of national opinion on the church question had operated in his favour, and in favour of all forms of free speculation. There had occurred in the Westminster Assembly itself, and more largely throughout the general community, that split of English Puritanism into the two opposed varieties of Presbyterianism on the one hand and Independency or Congregationalism on the other which explains the whole subsequent history of the Puritan revolution. Out of this theoretical discussion as to the constitution of the church there had grown the all-important practical question of toleration. The Presbyterians insisted that the whole population of England should necessarily belong to the one national Presbyterian Church, be compelled to attend its worship, and be subject to its discipline, while the Independents demanded that, if a Presbyterian Church should be set up as the national and state-paid church, there should at least be liberty of dissent from it, and toleration for those that chose to form themselves into separate congregations. Vehement within the Westminster Assembly itself, the controversy had attained wider dimensions out of doors, and had inwrought itself in a most remarkable manner with the conduct of the war. Orthodox Presbyterian Calvinists were still the majority of the Puritan body; but, in the new atmosphere of liberty, there had sprung up, from secret and long-suppressed seeds in the English mind, a wonderful variety of sects and denominations, mingling other elements with their Calvinism, or hardly Calvinistic at all,—most of them, it is true, fervidly Biblical and Christian after their different sorts, but not a few professing the most coolly inquisitive and sceptical spirit, and pushing their speculations to strange extremes of free-thinking. These sects, growing more and more numerous in the large towns, had become especially powerful in the English Parliamentary army. That army had, in fact, become a marching academy of advanced opinionists and theological debaters. Now, as all the new Puritan sects, differing however much among themselves, saw their existence and the perpetuity of their tenets threatened by that system of ecclesiastical uniformity which the Presbyterians proposed to establish, they had, one and all, abjured Presbyterianism, and adopted the opposite principle of Independency, with its appended principle of toleration. Hence an extraordinary conflict of policies among those who seemed to be all Parliamentarians, all united in fighting against the king. The auxiliary Scottish army, which had come into England in January 1643–44, and had helped the English generals to beat the king in the great battle of Marston Moor in July 1644, thought that he had then been almost sufficiently beaten, and that the object of the Solemn League and Covenant would be best attained by bringing him to such terms as should secure an immediate Presbyterian settlement and the suppression of the Independents and sectaries. In this the chief English commanders, such as Essex and Manchester, agreed substantially with the Scots. Cromwell, on the other hand, who was now the recognized head of the army Independents, did not think that the king had

been sufficiently beaten, even for the general purposes of the war, and was resolved that the war should be pushed on to a point at which a Presbyterian settlement should be impossible without guarantees for liberty of conscience and a toleration of non-Presbyterian sects. Through the latter part of 1644, accordingly, Milton had been saved from the penalties which his Presbyterian opponents would have inflicted on him by this general championship of liberty of opinion by Cromwell and the army Independents. Before the middle of 1645 he, with others who were on the black books of the Presbyterians as heretics, was safer still. Though the parliament had voted, in January 1644–45, that the future national church of England should be on the Presbyterian system, Cromwell and the Independents had taken care to have the question of toleration left open; and, within the next month or two, by Cromwell's exertions, a completely new face was put upon the war by the removal of all the chief officers that had been in command hitherto, and the equipment of the New Model army, with Fairfax as its commander-in-chief and Cromwell himself as lieutenant-general. The Scots and the stricter English Presbyterians looked on malignantly while this army took the field, calling it an "Army of Sectaries," and almost hoping it would be beaten. On June 14, 1645, however, there was fought the great battle of Naseby, utterly ruining the king at last, and leaving only relics of his forces here and there. Milton's position then may be easily understood. Though his first tendency on the church question had been to some form of a Presbyterian constitution for the church, he had parted utterly now from the Scots and Presbyterians, and become a partisan of Independency, having no dread of "sects and schisms," but regarding them rather as healthy signs in the English body-politic. He was, indeed, himself one of the most noted sectaries of the time, for in the lists of sects drawn out by contemporary Presbyterian writers special mention is made of one small sect who were known as *Miltonists* or *Divorcers*.

So far as Milton was concerned personally, his interest in the divorce speculation came to an end in July or August 1645, when, by friendly interference, a reconciliation was effected between him and his wife. The ruin of the king's cause at Naseby had suggested to the Powells that it might be as well for their daughter to go back to her husband after their two years of separation. It was not, however, in the house in Aldersgate Street that she rejoined him, but in a larger house, which he had taken in the adjacent street called Barbican, for the accommodation of an increasing number of pupils.

The house in Barbican was tenanted by Milton from about August 1645 to September or October 1647. Among his first occupations there must have been the revision of the proof sheets of the first edition of his collected poems. It appeared as a tiny volume, copies of which are now very rare, with the title *Poems of Mr John Milton, both English and Latin, composed at several times.* The title-page gives the date 1645, but January 1645–46 seems to have been the exact month of the publication. The appearance of the volume indicates that Milton may have been a little tired by this time of his notoriety as a prose-polemic, and desirous of being recognized once more in his original character of literary man and poet. But, whether because his pedagogic duties now engrossed him or for other reasons, very few new pieces were added in the Barbican to those that the little volume had thus made public. In English, there were only the four sonnets now numbered xi.–xiv., the first two entitled "On the Detraction which followed upon my writing certain Treatises," the third "To Mr Henry Lawes on his Airs," and the fourth "To the Religious Memory of Mrs Catherine Thomson," together with the powerful anti-Presbyterian invective or "tailed sonnet" entitled "On the New Forcers of Conscience under the Long Parliament"; and in Latin there were only the ode *Ad Joannem Rousium*, the trifle called *Apologus de Rustico et Hero*, and one interesting *Familiar Epistle* addressed to his Florentine friend Carlo Dati. Some family incidents of importance, however, appertain to this time of residence in Barbican. Oxford having surrendered to Fairfax in June 1646, the whole of the Powell family had to seek refuge in London, and most of them found shelter in Milton's house. His first child, a daughter named Anne, was born there on the 29th of July that year; on the 1st of January 1646–47 his father-in-law Mr Powell died there, leaving his affairs in confusion; and in the following March his own father died there, at the age of eighty-four, and was buried in the adjacent church of St Giles, Cripplegate. For the rest, the two years in Barbican are nearly blank in Milton's biography. The great Revolution was still running its course. For a time Charles's surrender of himself, in May 1646, to the auxiliary Scottish army rather than to Fairfax and Cromwell, and his residence with that Scottish army at Newcastle in negotiation with the Scots, had given the Presbyterians the advantage; but, after the Scots had evacuated England in January 1646–47, leaving Charles a captive with his English subjects, and especially after the English army had seized him at Holmby in June 1647 and undertaken the further management of the treaty with him, the advantage was all the other way. It was a satisfaction to Milton, and perhaps still a protection for him, that the "Army of Independents and Sectaries" had come to be really the masters of England.

From Barbican Milton removed, in September or October 1647, to a smaller house in that part of High Holborn which adjoins Lincoln's Inn Fields. His Powell relatives had now left him, and he had reduced the number of his pupils, or perhaps kept only his two nephews. But, though thus more at leisure, he did not yet resume his projected poem, but occupied himself rather with three works of scholarly labour which he had already for some time had on hand. One was the compilation in English of a complete history of England, or rather of Great Britain, from the earliest times; another was the preparation in Latin of a complete system of divinity, drawn directly from the Bible; and the third was the collection of materials for a new Latin dictionary. Milton had always a fondness for such labours of scholarship and compilation. Of a poetical kind there is nothing to record, during his residence in High Holborn, but an experiment in psalm-translation, in the shape of Psalms lxxx.–lxxxviii. done into service-metre in April 1648, and the *Sonnet to Fairfax*, written in September of the same year.—This last connects him again with the course of public affairs. The king, having escaped from the custody of the army chiefs, and taken refuge in the Isle of Wight, had been committed to closer custody there; all negotiation between him and parliament had been declared at an end; and the result would probably have been his deposition, but for the consequences of a secret treaty he had contrived to make with the Scots. By this treaty the Scots engaged to invade England in the king's behalf, rescue him from the English parliament and army, and restore him to his full royalty, while he engaged in return to ratify the Covenant, the Presbyterian system of church government, and all the other conclusions of the Westminster Assembly, throughout England, and to put down Independency and the sects. Thus, in May 1648, began what is called the Second Civil War, consisting first of new risings of the Royalists in various parts of England, and then of a conjunction of these with a great invasion

of England by a Royalist Scottish army, under the command of the duke of Hamilton. It was all over in August 1648, when the crushing defeat of the Scottish army by Cromwell in the three days' battle of Preston, and the simultaneous suppression of the English Royalist insurrection in the south-east counties by Fairfax's siege and capture of Colchester, left Charles at the mercy of the victors.—Milton's *Sonnet to Fairfax* was a congratulation to that general-in-chief of the parliament on his success at Colchester, and attested the exultation of the writer over the triumph of the Parliamentary cause. His exultation continued through what followed. After one more dying effort of the parliament at negotiation with Charles, the army took the whole business on itself. The king was brought from the Isle of Wight; the parliament, manipulated by the army officers, and purged of all members likely to impede the army's purpose, was converted into an instrument for that purpose; a court of high justice was set up for the trial of Charles; and on January 30, 1648–49, he was brought to the scaffold in front of Whitehall. By that act England became a republic, governed, without King or House of Lords, by the persevering residue or "Rump" of the recent House of Commons, in conjunction with an executive council of state, composed of forty-one members appointed annually by that House.

The first Englishman of mark out of parliament to attach himself openly to the new republic was John Milton. This he did by the publication of his pamphlet entitled *Tenure of Kings and Magistrates, proving that it is lawful, and hath been held so in all ages, for any who have the power, to call to account a Tyrant or wicked King, and, after due conviction, to depose and put him to death, if the ordinary Magistrate have neglected to do it.* It was out within a fortnight after the king's death, and was Milton's last performance in the house in High Holborn. The chiefs of the new republic could not but perceive the importance of securing the services of a man who had so opportunely and so powerfully spoken out in favour of their tremendous act, and who was otherwise so distinguished. In March 1648–49, accordingly, Milton was offered, and accepted, the secretaryship for foreign tongues to the council of state of the new Commonwealth. The salary was to be £288 a year, worth about £1000 a year now. To be near his new duties in attendance on the council, which held its daily sittings for the first few weeks in Derby House, close to Whitehall, but afterwards regularly in Whitehall itself, he removed at once to temporary lodgings at Charing Cross. In the very first meetings of council which Milton attended he must have made personal acquaintance with President Bradshaw, Fairfax, Cromwell himself, Sir Henry Vane, Whitlocke, Henry Marten, Hasilrig, Sir Gilbert Pickering, and the other chiefs of the council and the Commonwealth, if indeed he had not known some of them before. After a little while, for his greater convenience, official apartments were assigned him in Whitehall itself.

At the date of Milton's appointment to the secretaryship he was forty years of age. His special duty was the drafting of such letters as were sent by the council of state, or sometimes by the Rump Parliament, to foreign states and princes, with the examination and translation of letters in reply, and with personal conferences, when necessary, with the agents of foreign powers in London, and with envoys and ambassadors. As Latin was the language employed in the written diplomatic documents, his post came to be known indifferently as the secretaryship for foreign tongues or the Latin secretaryship. In that post, however, his duties, more particularly at first, were very light in comparison with those of his official colleague, Mr Walter Frost, the general secretary. Foreign powers held aloof from the English republic as much as they could; and, while Mr Frost had to be present in every meeting of the council, keeping the minutes, and conducting all the general correspondence, Milton's presence was required only when some piece of foreign business did turn up. Hence, from the first, his employment in very miscellaneous work. Especially, the council looked to him for everything in the nature of literary vigilance and literary help in the interests of the struggling Commonwealth. He was employed in the examination of suspected papers, and in interviews with their authors and printers; and he executed several great literary commissions expressly entrusted to him by the council. The first of these was his pamphlet entitled *Observations on Ormond's Articles of Peace with the Irish Rebels.* It was published in May 1649, and was in defence of the republic against a complication of Royalist intrigues and dangers in Ireland. A passage of remarkable interest in it is one of eloquent eulogy on Cromwell. More important still was the *Eikonoklastes* (which may be translated "Image-Smasher"), published by Milton in October 1649, by way of counterblast to the famous *Eikon Basilike* ("Royal Image"), which had been in circulation in thousands of copies since the king's death, and had become a kind of Bible in all Royalist households, on the supposition that it had been written by the royal martyr himself. A third piece of work was of a more laborious nature. In the end of 1649 there appeared abroad, under the title of *Defensio Regia pro Carolo I.*, a Latin vindication of the memory of Charles, with an attack on the English Commonwealth, intended for circulation on the Continent. As it had been written, at the instance of the exiled royal family, by Salmasius, or Claude de Saumaise, of Leyden, then of enormous celebrity over Europe as the greatest scholar of his age, it was regarded as a serious blow to the infant Commonwealth. To answer it was thought a task worthy of Milton, and he threw his whole strength into the performance through the year 1650, interrupting himself only by a new and enlarged edition of his *Eikonoklastes.* Not till April 1651 did the result appear; but then the success was prodigious. Milton's Latin *Pro Populo Anglicano Defensio*, as it was called, ran at once over the British Islands and the Continent, rousing acclamation everywhere, and received by scholars as an annihilation of the great Salmasius. Through the rest of 1651 the observation was that the two agencies which had co-operated most visibly in raising the reputation of the Commonwealth abroad were Milton's books and Cromwell's battles.—These battles of Cromwell, in the service of the Commonwealth he had founded, had kept him absent from the council of state, of which he was still a member, since shortly after the beginning of Milton's secretaryship. For nearly a year he had been in Ireland, as lord lieutenant, reconquering that country after its long rebellion; and then, for another year, he had been in Scotland, crushing the Royalist commotion there round Charles II., and annexing Scotland to the English republic. The annexation was complete on the 3d of September 1651, when Cromwell, chasing Charles II. and his army out of Scotland, came up with them at Worcester and gained his crowning victory. The Commonwealth then consisted of England, Ireland, and Scotland, and Cromwell was its supreme chief.—Through the eventful year 1651, it has been recently ascertained, Milton had added to the other duties of his secretaryship that of Government journalist. Through the whole of that year, if not from an earlier period, he acted as licenser and superintending editor of the *Mercurius Politicus*, a newspaper issued twice a week, of which Mr Marchamont Needham was the working editor and proprietor. Milton's hand is discernible in some of the leading articles.

About the end of 1651 Milton left his official rooms in

Whitehall for a house he had taken on the edge of St James's Park, in what was then called Petty France, Westminster, but is now York Street. The house existed till the other day, but has been pulled down. In Milton's time it was a villa-looking residence, with a garden, in a neighbourhood of villas and gardens. He had now more to do in the special work of his office, in consequence of the increase of correspondence with foreign powers. But he had for some time been in ailing health; and a dimness of eyesight which had been growing upon him gradually for ten years had been settling rapidly, since his labour over the answer to Salmasius, into total blindness. Actually, before or about May 1652, when he was but in his forty-fourth year, his blindness was total, and he could go about only with some one to lead him. Hence a re-arrangement of his secretarial duties. Such of these duties as he could perform at home, or by occasional visits to the Council Office near, he continued to perform; but much of the routine work was done for him by assistants, one of them a well-known German named Weckherlin, under the superintendence of Mr John Thurloe, who had succeeded Mr Walter Frost in the general secretaryship. Precisely to this time of a lull in Milton's secretaryship on account of his ill-health and blindness we have to refer his two great companion sonnets *To the Lord General Cromwell* and *To Sir Henry Vane the Younger*. To about the same time, or more precisely to the interval between May and September 1652, though the exact date is uncertain, we have to refer the death of his only son, who had been born in his official Whitehall apartments in the March of the preceding year, and the death also of his wife, just after she had given birth to his third daughter, Deborah. With the three children thus left him,—Anne, but six years old, Mary, not four, and the infant Deborah,—the blind widower lived on in his house in Petty France in such desolation as can be imagined. He had recovered sufficiently to resume his secretarial duties; and the total number of his dictated state letters for the single year 1652 is equal to that of all the state letters of his preceding term of secretaryship put together. To the same year there belong also three of his Latin *Familiar Epistles.* In December 1652 there was published *Joannis Philippi Angli Responsio ad Apologiam Anonymi Cujusdam Tenebrionis*, being a reply by Milton's younger nephew, John Phillips, but touched up by Milton himself, to one of several pamphlets that had appeared against Milton for his slaughter of Salmasius. The ablest and most scurrilous of these, which had just appeared anonymously at the Hague, with the title *Regii Sanguinis Clamor ad Cœlum adversus Parricidas Anglicanos* ("Cry of the Royal Blood to Heaven against the English Parricides"), Milton was reserving for his own attention at his leisure.

On the 20th of April 1653 there was Cromwell's great act of armed interference by which he turned out the small remnant of the Rump Parliament, dismissed their council of state, and assumed the government of England, Ireland, and Scotland into his own hands. For several months, indeed, he acted only as interim dictator, governing by a council of his officers, and waiting for the conclusions of that select body of advisers which he had called together from all parts of the country, and which the Royalists nicknamed "The Barebones Parliament." In December 1653, however, his formal sovereignty began under the name of the Protectorate, passing gradually into more than kingship. This change from government by the Rump and its council to government by a single military Lord Protector and his council was regarded by many as treason to the republican cause, and divided those who had hitherto been the united Commonwealth's men into the "Pure Republicans," represented by such men as Bradshaw and Vane, and the "Oliverians," adhering to the Protector. Milton, whose boundless admiration of Cromwell had shown itself already in his Irish tract of 1649 and in his recent sonnet, was recognized as one of the Oliverians. He remained in Oliver's service and was his Latin secretary through the whole of the Protectorate. For a while, indeed, his Latin letters to foreign states in Cromwell's name were but few,—Mr Thurloe, as general secretary, officiating as Oliver's right-hand man in everything, with a Mr Philip Meadows under him, at a salary of £200 a year, as deputy for the blind Mr Milton in foreign correspondence and translations. The reason for this temporary exemption of Milton from routine duty may have been that he was then engaged on an answer, by commission from the late Government, to the already-mentioned pamphlet from the Hague entitled *Regii Sanguinis Clamor.* Salmasius was now dead, and the Commonwealth was too stable to suffer from such attacks; but no Royalist pamphlet had appeared so able or so venomous as this in continuation of the Salmasian controversy. All the rather because it was in the main a libel on Milton himself did a reply from his pen seem necessary. It came out in May 1654, with the title *Joannis Miltoni Angli pro Populo Anglicano Defensio Secunda* ("Second Defence of John Milton, Englishman, for the People of England"). It is one of the most interesting of all Milton's writings. The author of the libel to which it replied was Dr Peter du Moulin the younger, a naturalized French Presbyterian minister, then moving about in English society, close to Milton; but, as that was a profound secret, and the work was universally attributed on the Continent to an Alexander Morus, a French minister of Scottish descent, then of much oratorical celebrity in Holland,—who had certainly managed the printing in consultation with the now deceased Salmasius, and had contributed some portion of the matter,—Milton had made this Morus the responsible person and the one object of his castigations. They were frightful enough. If Salmasius had been slaughtered in the former *Defensio*, Morus was murdered and gashed in this. His moral character was blasted by exposure of his antecedents, and he was blazoned abroad in Europe as a detected clerical blackguard. The terrific castigation of Morus, however, is but part of the *Defensio Secunda.* It contains passages of singular autobiographical and historical value, and includes laudatory sketches of such eminent Commonwealth's men as Bradshaw, Fairfax, Fleetwood, Lambert, and Overton, together with a long panegyric on Cromwell himself and his career, which remains to this day unapproached for elaboration and grandeur by any estimate of Cromwell from any later pen. From about the date of the publication of the *Defensio Secunda* to the beginning of 1655 the only specially literary relics of Milton's life are his translations of Psalms i.–viii. in different metres, done in August 1654, his translation of Horace's *Ode* i. 5, done probably about the same time, and two of his Latin *Familiar Epistles.* The most active time of his secretaryship for Oliver was from April 1655 onwards. In that month, in the course of a general revision of official salaries under the Protectorate, Milton's salary of £288 a year hitherto was reduced to £200 a year, with a kind of re-definition of his office, recognizing it, we may say, as a Latin secretaryship extraordinary. Mr Philip Meadows was to continue to do all the ordinary Foreign Office work, under Thurloe's inspection; but Milton was to be called in on special occasions. Hardly was the arrangement made when a signal occasion did occur. In May 1655 all England was horrified by the news of the massacre of the Vaudois Protestants by the troops of Emanuele II., duke of Savoy and prince of Piedmont, in consequence of their disobedience to an edict requiring them either to leave

their native valleys or to conform to the Catholic religion. Cromwell and his council took the matter up with all their energy; and the burst of indignant letters on the subject despatched in that month and the next to the duke of Savoy himself, Louis XIV. of France, Cardinal Mazarin, the Swiss cantons, the States-General of the United Provinces, and the kings of Sweden and Denmark, were all by Milton. His famous sonnet *On the late Massacre in Piedmont* was his more private expression of feeling on the same occasion. This sonnet was in circulation, and the case of the Vaudois Protestants was still occupying Cromwell, when, in August 1655, there appeared the last of Milton's great Latin pamphlets. It was his *Pro Se Defensio*, in answer to an elaborate self-defence which Morus had put forth on the Continent since Milton's attack on his character, and it consisted mainly of a re-exposure of that unfortunate clergyman. Thence, through the rest of Cromwell's Protectorate, Milton's life was of comparatively calm tenor. He was in much better health than usual, bearing his blindness with courage and cheerfulness; he was steadily busy with such more important despatches to foreign powers as the Protector, then in the height of his great foreign policy, and regarded with fear and deference by all European monarchs and states from Gibraltar to the Baltic, chose to confide to him; and his house in Petty France seems to have been, more than at any previous time since the beginning of his blindness, a meeting-place for friends and visitors, and a scene of pleasant hospitalities. The four sonnets now numbered xix.–xxii., one of them to young Mr Lawrence, the son of the president of Cromwell's council, and two of the others to Cyriack Skinner, belong to this time of domestic quiet, as do also no fewer than ten of his Latin *Familiar Epistles*. His second marriage belongs to the same years, and gleams even yet as the too brief consummation of this happiest time in the blind man's life. The name of his second wife was Katharine Woodcock. He married her on the 12th of November 1656; but, after only fifteen months, he was again a widower, by her death in childbirth in February 1657–58. The child dying with her, only the three daughters by the first marriage remained. The touching sonnet which closes the series of Milton's *Sonnets* is his sacred tribute to the memory on his second marriage and to the virtues of the wife he had so soon lost. Even after that loss we find him still busy for Cromwell. Mr Meadows having been sent off on diplomatic missions, Andrew Marvell had, in September 1657, been brought in, much to Milton's satisfaction, as his assistant or colleague in the Latin secretaryship; but this had by no means relieved him from duty. Some of his greatest despatches for Cromwell, including letters, of the highest importance, to Louis XIV., Mazarin, and Charles Gustavus of Sweden, belong to the year 1658.

One would like to know precisely in what personal relations Milton and Cromwell stood to each other. There is, unfortunately, no direct record to show what Cromwell thought of Milton; but there is ample record of what Milton thought of Cromwell. "Our chief of men," he had called Cromwell in his sonnet of May 1652; and the opinion remained unchanged. He thought Cromwell the greatest and best man of his generation, or of many generations; and he regarded Cromwell's assumption of the supreme power, and his retention of that power with a sovereign title, as no real suppression of the republic, but as absolutely necessary for the preservation of the republic, and for the safeguard of the British Islands against a return of the Stuarts. Nevertheless, under this prodigious admiration of Cromwell, there were political doubts and reserves. Milton was so much of a modern radical of the extreme school in his own political views and sympathies that he cannot but have been vexed by the growing conservatism of Cromwell's policy through his Protectorate. To his grand panegyric on Oliver in the *Defensio Secunda* of 1654 he had ventured to append cautions against self-will, over-legislation, and over-policing; and he cannot have thought that Oliver had been immaculate in these respects through the four subsequent years. The attempt to revive an aristocracy and a House of Lords, on which Cromwell was latterly bent, cannot have been to Milton's taste. Above all, Milton dissented *in toto* from Cromwell's church policy. It was Milton's fixed idea, almost his deepest idea, that there should be no such thing as an Established Church, or state-paid clergy, of any sort or denomination or mixture of denominations, in any nation, and that, as it had been the connexion between church and state, begun by Constantine, that had vitiated Christianity in the world, and kept it vitiated, so Christianity would never flourish as it ought till there had been universal disestablishment and disendowment of the clergy, and the propagation of the gospel were left to the zeal of voluntary pastors, self-supported, or supported modestly by their flocks. He had at one time looked to Cromwell as the likeliest man to carry this great revolution in England. But Cromwell, after much meditation on the subject in 1652 and 1653, had come to the opposite conclusion. The conservation of the Established Church of England, in the form of a broad union of all evangelical denominations of Christians, whether Presbyterians, or Independents, or Baptists, or moderate Old Anglicans, that would accept state-pay with state-control, had been the fundamental notion of his Protectorate, persevered in to the end. This must have been Milton's deepest disappointment with the Oliverian rule.

Cromwell's death on the 3d of September 1658 left the Protectorship to his son Richard. Milton and Marvell continued in their posts, and a number of the Foreign Office letters of the new Protectorate were of Milton's composition. Thinking the time fit, he also put forth, in October 1658, a new edition of his *Defensio Prima*, and, early in 1659, a new English pamphlet, entitled *Treatise of Civil Power in Ecclesiastical Causes*, ventilating those notions of his as to the separation of church and state which he had been obliged of late to keep to himself. To Richard's Protectorate also belongs one of Milton's Latin *Familiar Epistles*. Meanwhile, though all had seemed quiet round Richard at first, the jealousies of the army officers left about him by Oliver, and the conflict of political elements let loose by Oliver's death, were preparing his downfall. In May 1659 Richard's Protectorate was at an end. The country had returned with pleasure to what was called "the good old cause" of pure republicanism; and the government was in the hands of "the Restored Rump," consisting of the reassembled remains of that Rump Parliament which Cromwell had dissolved in 1653. To this change, as inevitable in the circumstances, or even promising, Milton adjusted himself. The last of his known official performances in his Latin secretaryship are two letters in the name of William Lenthall, as the speaker of the restored Rump, one to the king of Sweden and one to the king of Denmark, both dated May 15, 1659. Under the restored Rump, if ever, he seemed to have a chance for his notion of church-disestablishment; and, accordingly, in August 1659, he put forth, with a prefatory address to that body, a large pamphlet entitled *Considerations touching the likeliest means to remove Hirelings out of the Church*. The restored Rump had no time to attend to such matters. They were in struggle for their own existence with the army chiefs; and the British Islands were in that state of hopeless confusion and anarchy which, after passing through a brief phase of attempted military government (October to December 1659), and a second revival of the purely republican or Rump government (December 1659 to

the Restoration as one of "solitude." Nor was this the worst. His three daughters, on whom he ought now to have been able principally to depend, were his most serious domestic trouble. The poor motherless girls, the eldest in her seventeenth year in 1662, the second in her fifteenth, and the youngest in her eleventh, had grown up, in their father's blindness and too great self-absorption, ill-looked-after and but poorly educated; and the result now appeared. They "made nothing of neglecting him"; they rebelled against the drudgery of reading to him or otherwise attending on him; they "did combine together and counsel his maid-servant to cheat him in her marketings"; they actually "had made away some of his books, and would have sold the rest." It was to remedy this horrible state of things that Milton consented to a third marriage. The wife found for him was Elizabeth Minshull, of a good Cheshire family, and a relative of Dr Paget's. They were married on the 24th of February 1662–63, the wife being then only in her twenty-fifth year, while Milton was in his fifty-fifth. She proved an excellent wife; and the Jewin Street household, though the daughters remained in it, must have been under better management from the time of her entry into it. From that date Milton's circumstances must have been more comfortable, and his thoughts about himself less abject, than they had been through the two preceding years, though his feeling in the main must have been still that of his own Samson:—

> "Now blind, disheartened, shamed, dishonoured, quelled,
> To what can I be useful? wherein serve
> My nation, and the work from heaven imposed?
> But to sit idle on the household hearth,
> A burdenous drone, to visitants a gaze,
> Or pitied object."

That might be the appearance, but it was not the reality. All the while of his seeming degradation he had found some solace in renewed industry of various kinds among his books and tasks of scholarship, and all the while, more particularly, he had been building up his *Paradise Lost.* He had begun the poem in earnest, we are told, in his house in Petty France, in the last year of Cromwell's Protectorate, and then not in the dramatic form contemplated eighteen years before, but deliberately in the epic form. He had made but little way when there came the interruption of the anarchy preceding the Restoration and of the Restoration itself; but the work had been resumed in Jewin Street and prosecuted there steadily, by dictations of twenty or thirty lines at a time to whatever friendly or hired amanuensis chanced to be at hand. Considerable progress had been made in this way before his third marriage; and after that the work proceeded apace, his nephew Edward Phillips, who was then out in the world on his own account, looking in when he could to revise the growing manuscript.

It was not in the house in Jewin Street, however, that *Paradise Lost* was finished. Not very long after the third marriage, probably in 1664, there was a removal to another house, with a garden, not far from Jewin Street, but in a more private portion of the same suburb. This, which was to be the last of all Milton's London residences, was in the part of the present Bunhill Row which faces the houses that conceal the London artillery-ground and was then known as "Artillery Walk, leading to Bunhill Fields." Here the poem was certainly finished before July 1665; for, when, in that month, Milton and his family, to avoid the Great Plague of London, then beginning its fearful ravages, went into temporary country-quarters in a cottage in Chalfont St Giles, Buckinghamshire, about 23 miles from London, the finished manuscript was taken with him, in probably more than one copy. This we learn from his young Quaker friend, Thomas Ellwood, who had taken the cottage for him, and who was shown one of the manuscript copies, and allowed to take it away with him for perusal, during Milton's stay at Chalfont. Why the poem was not published immediately after his return to his Bunhill house in London, on the cessation of the Great Plague, does not distinctly appear, but may be explained partly by the fact that the official licenser hesitated before granting the necessary *imprimatur* to a book by a man of such notorious republican antecedents, and partly by the paralysis of all business in London by the Great Fire of September 1666. It was not till the 27th of April 1667 that Milton concluded an agreement with a publisher for the printing of his epic. By the agreement of that date, still extant, Milton sold to Samuel Simmons, printer, of Aldersgate Street, London, for £5 down, the promise of another £5 after the sale of a first edition of thirteen hundred copies, and the further promise of two additional sums of £5 each after the sale of two more editions of the same size respectively, all his copyright and commercial interest in *Paradise Lost* for ever. It was as if an author now were to part with all his rights in a volume for £17, 10s. down, and a contingency of £52, 10s. more in three equal instalments. The poem was duly entered by Simmons as ready for publication in the Stationers' Registers on the 20th of the following August; and shortly after that date it was out in London as a neatly printed small quarto, with the title *Paradise Lost: A Poem written in Ten Books: By John Milton.* The publishing price was 3s., equal to about 10s. 6d. now. It is worth noting as an historical coincidence that the poem appeared just at the time of the fall and disgrace of Clarendon.

The effect of the publication of *Paradise Lost* upon Milton's reputation can only be described adequately, as indeed it was consciously described by himself in metaphor, by his own words on Samson's feat of triumph over the Philistines:—

> But he, though blind of sight,
> Despised, and thought extinguished quite,
> With inward eyes illuminated,
> His fiery virtue roused
> From under ashes into sudden flame,
> And as an evening dragon came,
> Assailant on the perched roosts
> And nests in order ranged
> Of tame villatic fowl, but as an eagle
> His cloudless thunder bolted on their heads."

As the poem circulated and found readers, whether in the first copies sent forth by Simmons, or in subsequent copies issued between 1667 and 1669, with varied title-pages, and the latest of them with a prefixed prose "Argument," the astonishment broke out everywhere. "This man cuts us all out, and the ancients too" is the saying attributed to Dryden on the occasion; and it is the more remarkable because the one objection to the poem which at first, we are told, "stumbled many" must have "stumbled" Dryden most of all. Except in the drama, rhyme was then thought essential in anything professing to be a poem; blank verse was hardly regarded as verse at all; Dryden especially had been and was the champion of rhyme, contending for it even in the drama; and yet here was an epic not only written in blank verse, but declaring itself on that account to be "an example set, the first in English, of ancient liberty recovered to heroic poem from the troublesome and modern bondage of riming." That, notwithstanding this obvious blow struck by the poem at Dryden's pet literary theory, he should have welcomed the poem so enthusiastically and proclaimed its merits so emphatically, says much at once for his critical perception and for the generosity of his temper. An opinion proclaimed by the very chief of the Restoration literature could not but prevail among the contemporary scholars; and, though execration of the blind and unhanged regicide

had not ceased among the meaner critics, the general vote was that he had nobly redeemed himself. One consequence of his renewed celebrity was that visitors of all ranks again sought him out for the honour of his society and conversation. His obscure house in Artillery Walk, Bunhill, we are told, became an attraction now, "much more than he did desire," for the learned notabilities of his time.

The year 1669, when the first edition of *Paradise Lost* had been completely sold out, and Milton had received his second £5 on account of it, may be taken as the time of the perfect recognition of his pre-eminence among the English poets of his generation. He was then sixty years of age; and it is to about that year that the accounts that have come down to us of his personal appearance and habits in his later life principally refer. They describe him as to be seen every other day led about in the streets in the vicinity of his Bunhill residence, a slender figure, of middle stature or a little less, generally dressed in a grey cloak or overcoat, and wearing sometimes a small silver-hilted sword, evidently in feeble health, but still looking younger than he was, with his lightish hair, and his fair, rather than aged or pale, complexion. He would sit in his garden at the door of his house, in warm weather, in the same kind of grey overcoat, "and so, as well as in his room, received the visits of people of distinguished parts, as well as quality." Within doors he was usually dressed in neat black. He was a very early riser, and very regular in the distribution of his day, spending the first part, to his midday dinner, always in his own room, amid his books, with an amanuensis to read for him and write to his dictation. Music was always a chief part of his afternoon and evening relaxation, whether when he was by himself or when friends were with him. His manner with friends and visitors was extremely courteous and affable, with just a shade of stateliness. In free conversation, either at the midday dinner, when a friend or two happened, by rare accident, to be present, or more habitually in the evening and at the light supper which concluded it, he was the life and soul of the company, from his "flow of subject" and his "unaffected cheerfulness and civility," though with a marked tendency to the satirical and sarcastic in his criticisms of men and things. This tendency to the sarcastic was connected by some of those who observed it with a peculiarity of his voice or pronunciation. "He pronounced the letter *r* very hard," Aubrey tells us, adding Dryden's note on the subject: "*litera canina*, the dog-letter, a certain sign of a satirical wit." He was extremely temperate in the use of wine or any strong liquors, at meals and at all other times; and when supper was over, about nine o'clock, "he smoked his pipe and drank a glass of water, and went to bed." He suffered much from gout, the effects of which had become apparent in a stiffening of his hands and finger-joints, and the recurring attacks of which in its acute form were very painful. His favourite poets among the Greeks were Homer and the Tragedians, especially Euripides; among the Latins, Virgil and Ovid; among the English, Spenser and Shakespeare. Among his English contemporaries, he thought most highly of Cowley. He had ceased to attend any church, belonged to no religious communion, and had no religious observances in his family. His reasons for this were a matter for curious surmise among his friends, because of the profoundly religious character of his own mind; but he does not seem ever to have furnished the explanation. The matter became of less interest perhaps after 1669, when his three daughters ceased to reside with him, having been sent out, at considerable expense, "to learn some curious and ingenious sorts of manufacture that are proper for women to learn, particularly embroideries in gold or silver." After that the household in Bunhill consisted only of Milton, his wife, a single maid-servant, and the "man" or amanuensis who came in for the day.

The remaining years of Milton's life, extending through that part of the reign of Charles II. which figures in English history under the name of "The Cabal Administration," were by no means unproductive. In 1669 he published, under the title of *Accedence Commenced Grammar*, a small English compendium of Latin grammar that had been lying among his papers. In 1670 there appeared, in a rather handsome form, and with a prefixed portrait of him by Faithorne, done from the life, and the best and most authentic that now exists, his *History of Britain to the Norman Conquest*, being all that he had been able to accomplish of his intended complete history of England. In 1671 there followed his *Paradise Regained* and *Samson Agonistes*, bound together in one small volume, and giving ample proof that his poetic genius had not exhausted itself in the preceding great epic. His only publication in 1672 was a Latin digest of Ramist logic, entitled *Artis Logicæ Plenior Institutio*, of no great value, and doubtless from an old manuscript of his earlier days. In 1673, at a moment when the growing political discontent with the government of Charles II. and the conduct of his court had burst forth in the special form of a "No-Popery" agitation and outcry, Milton ventured on the dangerous experiment of one more political pamphlet, in which, under the title *Of True Religion, Heresy, Schism, Toleration, and what best means may be used against the growth of Popery*, he put forth, with a view to popular acceptance, as mild a version as possible of his former principles on the topics discussed. In the same year appeared the second edition of his *Minor Poems*. Thus we reach the year 1674, the last of Milton's life. One incident of that year was the publication of the second edition of *Paradise Lost*, with the poem rearranged as now into twelve books, instead of the original ten. Another was the publication of a small volume containing his Latin *Epistolæ Familiares*, together with the *Prolusiones Oratoriæ* of his student-days at Cambridge,—these last thrown in as a substitute for his Latin state letters in his secretaryship for the Commonwealth and the Protectorate, the printing of which was stopped by order from the Foreign Office. A third publication of the same year, and probably the very last thing dictated by Milton, was a translation of a Latin document from Poland relating to the recent election of the heroic John Sobieski to the throne of that kingdom, with the title *A Declaration or Letters Patents of the Election of this present King of Poland, John the Third.* It seems to have been out in London in August or September 1674. On the 8th of the following November, being a Sunday, Milton died, in his house in Bunhill, of "gout struck in," or gout-fever, at the age of sixty-five years and eleven months. He was buried, the next Thursday, in the church of St Giles, Cripplegate, beside his father, a considerable concourse attending the funeral.

Before the Restoration, Milton, what with his inheritance from his father, what with the official income of his Latin secretaryship, must have been a man of very good means indeed. Since then, however, various heavy losses, and the cessation of all official income, had greatly reduced his estate, so that he left but £900 (worth about or over £2700 now), besides furniture and household goods. By a word-of-mouth will, made in presence of his brother Christopher, he had bequeathed the whole to his widow, on the ground that he had done enough already for his "undutiful" daughters, and that there remained for them his interest in their mother's marriage portion of £1000, which had never been paid, but which their relatives, the Powells of Forest Hill, were legally bound for, and were now in circumstances to make good. The daughters, with the Powells probably abetting them, went to law with the widow to upset the will; and the decision of the court was that they should receive £100 each. With the £600 thus left, the widow, after some further stay in London, retired to Nantwich in her

native Cheshire. There, respected as a pious member of a local Baptist congregation, she lived till 1727, having survived her husband fifty-three years. By that time all the three daughters were also dead. The eldest, Ann Milton, who was somewhat deformed, had died not long after her father, having married "a master-builder," but left no issue; the second, Mary Milton, had died, unmarried, before 1694; and only the third, Deborah, survived as long as her step-mother. Having gone to Ireland, as companion to a lady, shortly before her father's death, she had married an Abraham Clarke, a silk-weaver in Dublin, with whom she returned to London about 1684, when they settled in the silk-weaving business in Spitalfields, rather sinking than rising in the world, though latterly some public attention was paid to Deborah, by Addison and others, on her father's account. One of her sons, Caleb Clarke, had gone out to Madras in 1703, and had died there as "parish-clerk of Fort George" in 1719, leaving children, of whom there are some faint traces to as late as 1727, the year of Deborah's death. Except for the possibility of further and untraced descent from this Indian grandson of Milton, the direct descent from him came to an end in his granddaughter, Elizabeth Clarke, another of Deborah's children. Having married a Thomas Foster, a Spitalfields weaver, but afterwards set up a small chandler's shop, first in Holloway and then in Shoreditch, she died at Islington in 1754, not long after she and her husband had received the proceeds of a performance of *Comus* got up by Dr Johnson for her benefit. All her children had predeceased her, leaving no issue.—Milton's brother Christopher, who had always been on the opposite side in politics, rose to the questionable honour of a judgeship and knighthood in the latter part of the reign of James II. He had then become a Roman Catholic,—which religion he professed till his death in retirement at Ipswich in 1692. Descendants from him are traceable a good way into the 18th century.—Milton's two nephews and pupils, Edward and John Phillips, both of them known as busy and clever hack-authors before their uncle's death, continued the career of hack authorship, most industriously and variously, though not very prosperously, through the rest of their lives, Edward in a more reputable manner than John, and with more of enduring allegiance to the memory of his uncle. Edward died about 1695; John was alive till 1706. Their half-sister, Ann Agar, the only daughter of Milton's sister by her second husband, had married, in 1673, a David Moore, of Sayes House, Chertsey; and it has so happened that the most flourishing of all the lines of descent from the poet's father is in this Agar-Moore branch of the Miltons.

Of masses of manuscript that had been left by Milton, some portions saw the light posthumously. Prevented, in the last year of his life, as has been mentioned, from publishing his Latin *State Letters* in the same volume with his Latin *Familiar Epistles*, he had committed the charge of the *State Letters*, prepared for the press, together with the completed manuscript of his Latin *Treatise of Christian Doctrine*, to a young Cambridge scholar, Daniel Skinner, who had been among the last of his amanuenses, and had, in fact, been employed by him specially in copying out and arranging those two important MSS. Negotiations were on foot, after Milton's death, between this Daniel Skinner and the Amsterdam printer, Daniel Elzevir, for the publication of both MSS., when the English Government interfered, and the MSS. were sent back by Elzevir, and thrown aside, as dangerous rubbish, in a cupboard in the State Paper Office. Meanwhile, in 1676, a London bookseller, named Pitt, who had somehow got into his possession a less perfect, but still tolerably complete, copy of the *State Letters*, had brought out a surreptitious edition of them, under the title *Literæ Pseudo-Senatus Anglicani, necnon Cromwelli, nomine et jussu conscriptæ.* No other posthumous publication of Milton's appeared till 1681, when another bookseller put forth a slight tract entitled *Mr John Milton's Character of the Long Parliament and Assembly of Divines*, consisting of a page or two, of rather dubious authenticity, said to have been withheld from his *History of Britain* in the edition of 1670. In 1682 appeared *A Brief History of Moscovia and of other less-known Countries lying eastward of Russia as far as Cathay*, undoubtedly Milton's, and a specimen of those prose compilations with which he sometimes occupied his leisure. Of the fate of his collections for a new Latin *Dictionary*, which had swelled to three folio volumes of MS., all that is known is that, after having been used by Edward Phillips for some of *his* pedagogic books, they came into the hands of a committee of Cambridge scholars, and were used for that Latin dictionary of 1693, called *The Cambridge Dictionary*, on which Ainsworth's *Dictionary* and all subsequent Latin dictionaries of English manufacture have been based. In 1698 there was published in three folio volumes, under the editorship of John Toland, the first collective edition of Milton's prose works, professing to have been printed at Amsterdam, though really printed in London. A very interesting folio volume, published in 1743 by "John Nickolls, junior," under the title of *Original Letters and Papers of State addressed to Oliver Cromwell*, consists of a number of intimate Cromwellian documents that had somehow come into Milton's possession immediately after Cromwell's death, and were left by him confidentially to the Quaker Ellwood. Finally, a chance search in the London State Paper Office in 1823 having discovered the long-lost parcel containing the MSS. of Milton's Latin *State Letters* and his Latin *Treatise of Christian Doctrine*, as these had been sent back from Amsterdam a hundred and fifty years before, the *Treatise on Christian Doctrine* was, by the command of George IV., edited and published in 1825 by the Rev. C. R. Sumner, keeper of the Royal Library, and afterwards bishop of Winchester, under the title of *Joannis Miltoni Angli De Doctrina Christiana Libri Duo Posthumi.* An English translation, by the editor, was published in the same year.

Information, rather than criticism, has seemed proper in such an article as the present. What little of closing remark is necessary will best connect itself with the obvious fact of the division of Milton's literary life into three almost mechanically distinct periods, viz.:—(1) the time of his youth and minor poems, (2) his middle twenty years of prose polemics, and (3) the time of his later Muse and greater poems.

Had Milton died in 1640, when he was in his thirty-second year, and had his literary remains been then collected, he would have been remembered as one of the best Latinists of his generation and one of the most exquisite of minor English poets. In the latter character, more particularly, he would have taken his place as one of that interesting group or series of English poets, coming in the next forty years after Spenser, who, because they all acknowledged a filial relationship to Spenser, may be called collectively The Spenserians. In this group or series, counting in it such other true poets of the reigns of James I. and Charles I. as Phineas and Giles Fletcher, William Browne, and Drummond of Hawthornden, Milton would have been entitled, by the small collection of pieces he had left, and which would have included his *Ode on the Nativity*, his *L'Allegro* and *Il Penseroso*, his *Comus*, and his *Lycidas*, to recognition as indubitably the very highest and finest. There was in him that peculiar Spenserian something which might be regarded as the poetic faculty in its essence, with a closeness and perfection of verbal finish not to be found in the other Spenserians, or even in the master himself. A very discerning critic might have gone deeper, as we can now. Few as the pieces were, and owning discipleship to Spenser as the author did, he was a Spenserian with a difference belonging to his own constitution,—which prophesied, and indeed already exhibited, the passage of English poetry out of the Spenserian into a kind that might be called the Miltonic. This Miltonic something, distinguishing the new poet from other Spenserians, was more than mere perfection of literary finish. It consisted in an avowed consciousness already of the *os magna soniturum*, "the mouth formed for great utterances," that consciousness resting on a peculiar substratum of personal character that had occasioned a new theory of literature. "He who would not be frustrate of his hope to write well hereafter on laudable things ought himself to be a true poem" was Milton's own memorable expression afterwards of the principle that had taken possession of him from his earliest days; and this principle of moral manliness as the true foundation of high literary effort, of the inextricable identity of all literary productions in kind, and their coequality in worth, with the personality in which they have their origin, might have been detected, in more or less definite shape, in all or most of the minor poems. It is a specific form of that general Platonic doctrine of the invincibility of virtue which runs through his *Comus*, and which is summed up in the Miltonic motto of the closing lines:—

> "Mortals that would follow me,
> Love Virtue: she alone is free.
> She can teach ye how to climb
> Higher than the sphery chime;
> Or, if Virtue feeble were,
> Heaven itself would stoop to her."

That a youth and early manhood of such poetical promise should have been succeeded by twenty years of all but incessant prose polemics has been a matter of regret with many. Why should the author of *Comus* and *Lycidas*, instead of keeping to the poetic craft, have employed himself for twenty years in the drudgery and turmoil of prose pamphleteering on questions of church and state, with nothing in verse to glitter across the long morass but a slight chain of biographical and historical sonnets? Surely this is a most shallow and most unmasculine judgment. Is nothing due to Milton's own explanation of the reasons that drew him, at the beginning of the English Revolution, out of his literary projects and dreamings, into active partisanship with the cause which his reason favoured? Hear what he says would have been the reproach of his own conscience to him, evening and morning, if he had abstained from such partisanship and persisted in his poetic privacy. "Ease and leisure was given thee for thy retired thoughts out of the sweat of other men. Thou hadst the diligence, the parts, the language of a man, if a vain subject were to be adorned or beautified; but, when the cause of God and His church was to be pleaded, for which purpose that tongue was given thee which thou hast, God listened if He could hear thy voice among His zealous servants, but thou wert dumb as a beast: from henceforward *be* that which thine own brutish silence hath made thee." Or, if this should be in too high a strain for the ordinary modern apprehension, may not one ask, more

simply, whether such controversial work as Milton did plunge into, and persevere in for twenty years, was unworthy, after all, of him or his powers? Do not hundreds of men, accounted among the ablest in the world, spend their lives precisely in such work of controversy on contemporary questions; and are not some of the men of noblest reputation in the world's history remembered for nothing else? If Burke, whose whole public career consisted in a succession of speeches and pamphlets, is looked back upon as one of the greatest men of his century on their account, why should there be such regret over the fact that Milton, after having been the author of *Comus* and *Lycidas*, became for a time the prose orator of *his* earlier and more tumultuous generation? The truth is that it is not his exchange of poetry for prose oratory that is objected to, so much as the nature of his prose oratory, the side he took, the opinions he advocated. English scholarship and English literary criticism have not yet sufficiently recovered from that inherited sycophancy to the Restoration which has covered with a cloud the preceding twenty years of the "Great Rebellion," voting that period of English history to be unrespectable, and all its phenomena of Presbyterianism, the Solemn League and Covenant, Independency, the sects, English republicanism, &c., to be matters of obsolete jargon, less worthy of attention than a Roman agrarian law or the names of Horace's mistresses. When this unscholarly state of temper has passed, there will be less disposition to distinguish between Milton as the poet and Milton as the prose writer. While some may recognize, with the avidity of assent and partisanship, the fact that there are in Milton's prose writings notions of much value and consequence that have not yet been absorbed into the English political mind, there will be a general agreement at least as to the importance of those pamphlets historically. It will be perceived that he was not only the greatest pamphleteer of his generation, head and shoulders above the rest, but also that there is no life of that time, not even Cromwell's, in which the history of the great Revolution in its successive phases, so far as the deep underlying ideas and speculations were concerned, may be more intimately and instructively studied than in Milton's. Then, on merely literary grounds, what an interest in those prose remains! Not only of his *Areopagitica*, admired now so unreservedly because its main doctrine has become axiomatic, but of most of his other pamphlets, even those the doctrine of which is least popular, it may be said confidently that they answer to his own definition of "a good book," by containing somehow "the precious life-blood of a master-spirit." From the entire series there might be a collection of specimens, unequalled anywhere else, of the capabilities of that older, grander, and more elaborate English prose of which the Elizabethans and their immediate successors were not ashamed, though it has fallen into disrepute now in comparison with the easier and nimbler prose which came in with Dryden. Nor will readers of Milton's pamphlets continue to accept the hackneyed observation that his genius was destitute of humour. Though his prevailing mood was the severely earnest, there are pages in his prose writings, both English and Latin, of the most laughable irony, reaching sometimes to outrageous farce, and some of them as worthy of the name of humour as anything in Swift. Here, however, we touch on what is the worst feature in some of the prose pamphlets,—their measureless ferocity, their boundless licence in personal scurrility. With all allowance for the old custom of those days, when controversy was far more of a life-and-death business than it is now, as well as for the intrinsic soundness of Milton's rule of always discerning the *man* behind the *book*, it is impossible for the most tolerant of modern readers to excuse Milton in this respect to the full extent of his delinquencies.

While it is wrong to regard Milton's middle twenty years of prose polemics as a degradation of his genius, and while the fairer contention might be that the youthful poet of *Comus* and *Lycidas* actually promoted himself, and became a more powerful agency in the world and a more interesting object in it for ever, by consenting to lay aside his "singing robes" and spend a portion of his life in great prose oratory, who does not exult in the fact that such a life was rounded off so miraculously at the close by a final stage of compulsory calm, when the "singing robes" could be resumed, and *Paradise Lost, Paradise Regained*, and *Samson Agonistes* could issue in succession from the blind man's chamber? Of these three poems, and what they reveal of Milton, no need here to speak at length. *Paradise Lost* is one of the few monumental works of the world, with nothing in modern epic literature comparable to it except the great poem of Dante. This is best perceived by those who penetrate beneath the beauties of the merely terrestrial portion of the story, and who recognize the coherence and the splendour of that vast symbolic phantasmagory by which, through the wars in heaven and the subsequent revenge of the expelled archangel, it paints forth the connexion of the whole visible universe of human cognizance and history with the grander, pre-existing, and still environing world of the eternal and inconceivable. To this great epic *Paradise Regained* is a sequel, and it ought to be read as such. The legend that Milton preferred the shorter epic to the larger is quite incorrect. All that is authentic on the subject is the statement by Edward Phillips that, when it was reported to his uncle that the shorter epic was "generally censured to be much inferior to the other," he "could not hear with patience any such thing." The best critical judgment now confirms Milton's own, and pronounces *Paradise Regained* to be not only, within the possibilities of its briefer theme, a worthy sequel to *Paradise Lost*, but also one of the most edifying and artistically perfect poems in any language. Finally, the poem in which Milton bade farewell to the Muse, and in which he reverted to the dramatic form, proves that to the very end his right hand had lost none of its power or cunning. *Samson Agonistes* is the most powerful drama in our language after the severe Greek model, and it has the additional interest of being so contrived that, without strain at any one point, or in any one particular, of the strictly objective incidents of the Biblical story which it enshrines, it is yet the poet's own epitaph and his condensed autobiography. All in all, now that those three great poems of Milton's later life have drawn permanently into their company the beautiful and more simple performances of his youth and early manhood, so that we have all his English poetry under view at once, the result has been that this man, who would have had to be remembered independently as the type of English magnanimity and political courage, is laurelled also as the supreme poet of his nation, with the single exception of Shakespeare.

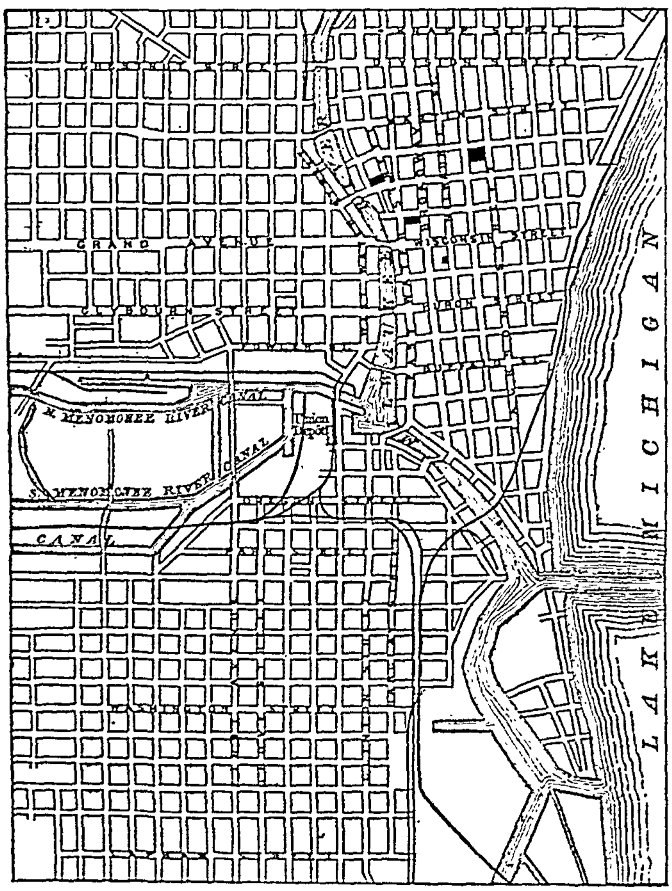
Much light is thrown upon Milton's mind in his later life, and even upon the poems of that period, by his posthumous Latin *Treatise of Christian Doctrine*. It differs from all his other prose writings of any importance in being cool, abstract, and didactic. Professing to be a system of divinity derived directly from the Bible, it is really an exposition of Milton's metaphysics and of his reasoned opinions on all questions of philosophy, ethics, and politics. The general effect is to show that, though he is rightly regarded as the very genius of English Puritanism, its representative poet and idealist, yet he was not a Puritan of what may be called the first wave, or that wave of Calvinistic orthodoxy which broke in upon the absolutism of Charles and Laud, and set the English Revolution agoing. He belonged distinctly to that larger and more persistent wave of Puritanism which, passing on through Independency, included at length an endless variety of sects, many of them rationalistic and free-thinking in the extreme, till, checked by the straits of the Restoration, it had to contract its volume for a while, and to reappear, so far as it could reappear at all, in the new and milder guise of what has ever since been known as English Liberalism. For example, the treatise shows that Milton in his later life was not an orthodox Trinitarian, but an anti-Trinitarian of that high Arian order, counting Sir Isaac Newton among its subsequent English adherents, which denied the coessentiality or coequality of Christ with absolute Deity, but regarded him as clothed with a certain derivative divinity of a high and unfathomable kind. It shows him also to have been Arminian, rather than Calvinistic, in his views of free will and predestination. It shows him to have been no Sabbatarian, like the Puritans of the first wave, but most strenuously anti-Sabbatarian. Indeed one of its doctrines is that the Decalogue is no longer the standard of human morality, and that Christian liberty is not to be bounded by its prohibitions or by any sacerdotal code of ethics founded on these. Hence, in the treatise, not only a repetition of Milton's views on the marriage subject and of other peculiar tenets of his that had been set forth in his pamphlets, but some curious and minute novelties of opinion besides. By far the most important revelation of the treatise, however, consists in the very definite statement it makes of Milton's metaphysical creed and of the connexion of that creed in his mind with the revealed theology of Christianity. While, ontologically, he starts from a pure spiritualistic theism, or from the notion of one infinite and eternal Spirit as the self-subsisting God and author of all being, cosmologically his system is that of a pantheistic materialism, which conceives all the present universe, all that we call creation, as consisting of diverse modifications, inanimate or animate, of one primal matter, which was originally nothing else than an efflux or emanation from the very substance of God. Angels and men, no less than the brute world and the things we call lifeless, are formations from this one original matter, only in higher degrees and endowed with soul and free will. Hence any radical distinction between matter and spirit, body and soul, is, Milton holds, fallacious. The soul of man, he holds, is not something distinct from the body of man and capable of existing apart, but is actually bound up with the bodily organism. Therefore, when the body dies, the soul dies also, and the whole man ceases to exist. The immortality revealed in Scripture is, therefore, not a continued existence of the soul in an immaterial condition immediately after death, but a miraculous revival of the whole man, soul and body together, at the resurrection, after an intermediate sleep. In such a resurrection, with a final judgment, a reign of Christ, and a glorification of the saints in a new heaven and a new earth, Milton declares his absolute belief. But, indeed, throughout the treatise, with all its differences from the orthodox interpretations of the Bible, nothing is more remarkable than the profoundness of the reverence avowed for the Bible itself. The very initial

principle of the treatise is that, as the Bible is a revelation from God of things that man could not have found out for himself, all that the Bible says on any matter is to be accepted implicitly, in the plain sense of the words, and without sophistication, however strange it may seem to the natural human reason. Hence, in all those essentials of Christianity which consist in the doctrines of the fall of man, atonement by Christ, and restoration and sanctification through Christ only, Milton is at one with the great body of Christians. Altogether, what the treatise makes clear is that, while Milton was a most fervid theist and a genuine Christian, believing in the Bible, and valuing the Bible over all the other books in the world, he was at the same time one of the most intrepid of English thinkers and theologians.

For further information reference may be made to Masson's *Life of Milton and History of his Time*, 6 vols. (1859–80), and to his editions of Milton's *Poetical Works* (Cambridge edition in 3 vols., 1874, and smaller 3 vol. ed., 1882), as well as to Todd's variorum edition of the *Poetical Works*, with Life (5th ed., 1852), to Keightley's *Life, Opinions, and Writings of Milton* (1855), to *Milton und Seine Zeit*, by Alfred Stern (1877-79), and to Mr Mark Pattison's *Milton* in Mr Morley's series of "English Writers." Collective editions of the prose works since that of 1698 are—Symmons's (7 vols., 1806); Pickering's, with *Life* by Mitford (8 vols., prose and verse together, 1851); and St John's, in Bohn's Standard Library (5 vols., 1848–53). This last includes a revised edition of Bishop Sumner's translation of the *Treatise of Christian Doctrine*, originally published in 1825. (D. MA.)

MILWAUKEE, the largest city in the State of Wisconsin, United States, is situated on the west shore of Lake Michigan, 100 miles north of its southern end, 80 miles north of Chicago, and 1000 miles north-west of New York by rail, in 43° 3′ N. lat., 87° 56′ W. long. (44 min. W. of Washington). The shore of the lake is 600 feet above the level of the sea.

The Milwaukee and Menomonee rivers unite in the centre of the business portion of the city, about half a mile from their entrance to Lake Michigan, where they are joined by a third and smaller stream—the Kinnikinnic. A bay 6 miles from cape to cape, and 3 miles broad,



Plan of Milwaukee.

stretches in front of the city, which commands a fine water view, the ground rising along the shore 80 feet above the level of the lake, then gradually sloping westward to the Milwaukee river, and again rising on the west and north to a height of 125 feet. The ground also rises to a commanding elevation south of the valley of the Menomonee. Few cities present so many natural attractions of site, as indeed its Indian name indicates ("the beautiful hollow or bay"); and art has added to nature. In the residence parts of the city there are miles of avenues from 70 to 100 feet wide, lined on both sides with elms and maples, behind which stand handsome houses with spacious lawns, fountains, and evergreens, giving the appearance of a continuous park. The material used for building is largely the cream-coloured brick made in the vicinity, from which Milwaukee is sometimes called the "Cream City." The climate, tempered by the great lake, is remarkably pleasant and healthy. The mean temperature, as shown by the records of twenty years, is 46°·7 Fahr. The coldest month is January (average 22°·37), the hottest July (70°·4).[1] During the last nine years the average death-rate has been but 20 per 1000, showing it to be one of the healthiest of American cities. Besides a full complement of the usual religious and charitable institutions, there is adjoining the city the national home for disabled United States volunteer soldiers, consisting of several buildings situated in grounds of 400 acres extent, which serve the purpose of a city park. There are numerous lodges belonging to the freemasons and other guilds; and the Turners' societies, which embrace a large membership and own some valuable buildings, have done much to create and keep up the practice of athletic exercises among the citizens. Two excellent musical societies are also established here.

Before the year 1835 Milwaukee was known only as an Indian trading-post occupied by a Frenchman named Solomon Juneau, who is generally spoken of as the founder of the city. The total inhabitants in 1838 numbered only 700; in 1840 there were 1712; but in 1846 the population amounted to 9666, in 1850 to 20,061, in 1855 to 30,118, in 1860 to 45,246, in 1870 to 71,440, and in 1880 to 115,578 (57,475 males, 58,103 females). In 1882 the population was estimated at 130,000,—more than one half of them of foreign parentage, a very large majority being Germans. Notwithstanding the multitude of nationalities represented in the population, there are few cities more orderly and law-abiding, the number of police employed being less than one for every 1500 inhabitants. Another feature worthy of mention is the large proportion of families who own their own houses, and this is true not only as to the mercantile and professional classes, but especially as to the labouring population. Although the grain trade, formerly very large here, has now greatly diminished, the growth and prosperity of the city have not materially suffered, owing to the development of manufacturing industries, for which the low rents, healthy climate, and advantageous location make it well adapted. About a sixth of the population are engaged in the manufacture of clothing, cigars, cooperage, leather, bricks, sashes, doors, and blinds, machinery, and flour (of which one million of barrels are annually made), and in meat-packing. Milwaukee has become famous for its "lager beer," of which there are one million of barrels annually produced, valued at $8,000,000. The lake commerce is very large. The tonnage entered and cleared in 1880 was 5,322,373 tons, being about as large as that of Baltimore, Boston, or Philadelphia. The Wisconsin Central, the Milwaukee and Lake Shore, the Milwaukee and Northern, and the Chicago, Milwaukee, and St Paul Railways have their head offices here, and the last-named, owning 4000 miles of lines, has immense workshops in the Menomonee valley near the city.

Milwaukee is governed by a mayor and a common council of thirty-nine aldermen. The streets and public buildings are under the charge of the board of public works,

[1] The monthly averages for twenty years are:—January, 22°·37; February, 25°·13; March, 33°·35; April, 43°·94; May, 53°·75; June, 64°·39; July, 70°·04; August, 67°·89; September, 61°·68; October, 48°·48; November, 36°·27; December, 25°·53.

composed of three commissioners and the city engineer, all subject to the common council. A bountiful supply of water is obtained from the lake, and the streets are well supplied with sewers. The value of property as assessed for taxation was $62,000,000 in 1882,—the city debt being $2,500,000, mostly for the water-works, which are city property.

There is an efficient system of public schools under a superintendent and board of school commissioners, the value of the buildings with their sites being estimated at $700,000. For the higher education there are a high school, a normal school, and three commercial colleges, while the Roman Catholics and Lutherans have several excellent denominational seminaries and colleges. A public library belonging to the city contained 20,000 volumes in 1882. (J. J.)

MIMICRY is the name given in biology to the advantageous resemblance (usually protective) which one species of animal or plant often shows to another. The word was first applied in this metaphorical sense by Mr W. H. Bates, and it has since been accurately defined and limited, in its biological application, by Mr A. R. Wallace. Briefly put, the essence of the phenomenon of mimicry consists in the following relation. A certain species of plant or animal possesses some special means of defence from its enemies, such as a sting, a powerful and disagreeable odour, a nauseous taste, or a hard integument. Some other species inhabiting the same district or a part of it, and not itself provided with the same special means of defence, closely resembles the first species in all external points of form and colour, though often very different in structure and unrelated in the biological order. For example, a South-American family of butterflies, the *Heliconidæ*, are distinguished by their very varied and beautiful colours, and their slow and weakly flight; they might easily be captured by insectivorous birds, but their remains are never found on the ground amongst the rejected wings of other butterflies which cover the soil in many places. They also possess a strong pungent odour, which clings to the fingers for many days; and this fact led Mr Wallace to suspect that they have a disagreeable taste, and would not therefore be eaten by birds after a single trial. Mr Belt has since experimentally proved the truth of that belief. But among the totally distinct family of the *Pieridæ*, most of which are white, there is a genus of small butterflies, known as *Leptalis*, edible by birds, some species of which are white like their allies, while the greater number exactly resemble one or other of the *Heliconidæ* in the peculiar shape and colouring of their wings. As regards structure, the two families are widely different; yet the resemblance of a species of one family to a species of the other is often so close that Mr Bates and Mr Wallace, experienced entomologists, frequently mistook them for one another at the time of capture, and only discovered their mistake upon nearer examination. Mr Bates observed several species or varieties of *Leptalis* in the Amazons valley, each of which more or less exactly copied one of the *Heliconidæ* in its own district. Accordingly, they seem to be mistaken by birds for the uneatable insects they mimic, and so to be benefited by their resemblance. This, which may perhaps be regarded as the most typical instance of true mimicry, is also the first to which the word was applied.

In considering the phenomena under review, it may be well to give first the chief observed facts, which are quite independent of any particular explanation, and then the theory which has been started to account for them by Mr Bates and Mr Wallace. Before doing so, however, true mimicry should be carefully discriminated from one or two superficially similar modes of resemblance among organic beings, whose real implications are very different. It must not be confused with mere accidental or adaptive resemblance, due either to simple chance or to similarity of external conditions. As a case of the first sort, we may adduce the real or fancied resemblance between certain orchids and flies or spiders; as a case of the second sort, we may take certain African *Euphorbiaceæ*, which, growing in dry deserts, have acquired a very close likeness to the cactuses that cover the equally dry deserts of Mexico; or again the sub-Antarctic gallinaceous bird, *Chionis alba*, which, living on the sea-shore, has acquired a coloration like that of the gulls, together with the legs of a wader. These resemblances, however, do not as such subserve any function. The species apparently mimicking and the species apparently mimicked either do not inhabit the same district or do not come into any definite relation with one another. The likeness is either accidental, or else it is due to similar adaptation to similar circumstances. In cases of true mimicry, on the other hand, the mimicking species derives a direct advantage from its likeness to the species mimicked; the resemblance is deceptive; and this is equally true whether we suppose the mimicry to be produced by creative design or by natural selection. On either hypothesis, however it came by its likeness, the mimicking species escapes certain enemies or obtains certain sorts of food by virtue of its resemblance to some other kind.

It should also be added that the word mimicry, as applied to such cases, is used only in a metaphorical sense. It is not intended to imply any conscious or voluntary imitation by one species of the appearance or habits of another. All that is meant is the fact of an advantageous resemblance, a delusive similarity, which gives the mimicking animal or plant some extra protection or some special means of acquiring food which it would not otherwise have possessed but for its likeness to the creature mimicked.

Taking animals first, mimicry does not occur very frequently among the higher classes. In the vertebrates it is comparatively rare, and among mammals probably only one good case has yet been adduced. This is that of *Cladobates*, an insectivorous genus of the Malayan region, many species of which closely resemble squirrels in size, in colour, and in the bushiness and posture of the tail. It has been suggested by Mr Wallace (from whom most of the following examples have been borrowed) that *Cladobates* may thus be enabled to approach the insects and small birds which form its prey under the disguise of the harmless fruit-eating squirrel. In this case, as in some others, the resemblance is not protective, but is apparently useful to the animal in the quest for food.

Among birds, Mr Wallace has pointed out that the general likeness of the cuckoo, a weak and defenceless group, to the hawks and gallinaceous tribe makes some approach to real mimicry. But besides such vague resemblances there are one or two very distinct cases of true mimicry in this class of vertebrates. In Australia and the Moluccas lives a genus of dull-hued honey-suckers, *Tropidorhynchus*, consisting of large, strong, active birds, with powerful claws and sharp beaks. They gather together in noisy flocks, and are very pugnacious, driving away crows and even hawks. In the same countries lives a group of orioles, forming the genus *Mimeta*; and these, which are much weaker birds, have not the usual brilliant colouring of their allies the golden orioles, but are usually olive-green or brown. In many cases species of *Mimeta* closely resemble the *Tropidorhynchi* inhabiting the same island. For example, on the island of Bouru are found the *Tropidorhynchus bouruensis* and *Mimeta bouruensis*, the latter of which mimics the former in the particulars thus noted by Mr Wallace:—"The upper and under surfaces of the two birds are exactly of the same tints of dark and light brown. The *Tropidorhynchus* has a large

bare black patch round the eyes; this is copied in the *Mimeta* by a patch of black feathers. The top of the head of the *Tropidorhynchus* has a scaly appearance from the narrow scale-formed feathers, which are imitated by the broader feathers of the *Mimeta* having a dusky line down each. The *Tropidorhynchus* has a pale ruff formed of curious recurved feathers on the nape (which has given the whole genus the name of friar-birds); this is represented in the *Mimeta* by a pale band in the same position. Lastly, the bill of the *Tropidorhynchus* is raised into a protuberant keel at the base, and the *Mimeta* has the same character, although it is not a common one in the genus. The result is that on a superficial examination the birds are identical, although they have important structural differences, and cannot be placed near each other in any natural arrangement." Allied species of *Tropidorhynchus* in Ceram and Timor are similarly mimicked by the local *Mimeta* of each island. Mr Osbert Salvin has likewise noticed a case of mimicry among the birds of prey near Rio Janeiro. An insect-eating hawk, *Harpagus diodon*, is closely resembled by a bird-eating hawk, *Accipiter pileatus*. Here the advantage seems to be that the small birds have learned not to fear the *Harpagus*, and the *Accipiter* is able to trade upon the resemblance by catching them unawares, both birds being reddish-brown when seen from beneath. But the *Accipiter* has the wider range of the two; and where the insect-eating species is not found it no longer resembles it, but varies in the under wing-coverts to white. Here again the resemblance, though advantageous, is not protective.

Among reptiles, Mr Wallace has instanced some curious cases where a venomous tropical American genus of snakes, *Elaps*, with brightly-banded colours, is closely mimicked by several genera of harmless snakes, having no affinity with it, but inhabiting the same region. Thus the poisonous *Elaps fulvus* of Guatemala has black bands on a coral-red ground; the harmless *Pliocerus æqualis* of the same district is coloured and banded precisely like it. The likeness affords the unarmed snakes a great protection, because other animals probably will not touch them, mistaking them for the venomous kinds.

It is among the invertebrates, however, and especially among insects, that cases of mimicry are most frequent and were first observed. In the order *Lepidoptera*, besides the classical instance of *Leptalis* and the *Heliconidæ*, a genus of another family, the *Erycinidæ*, also mimics the same group. The flocks of one species of *Ithomia*, an uneatable butterfly, often have flying with them a few individuals of three other widely different genera, quite indistinguishable from them when on the wing. In the tropics of the Old World, the *Danaidæ* and *Acræidæ* possess a similar protective odour, and are equally abundant in individuals; they are closely mimicked by various species of *Papilio* and *Diadema*. Mr Trimen, in a paper on "Mimetic Analogies among African Butterflies," gives a list of sixteen species or varieties of *Diadema* or its allies, and ten species of *Papilio*, each of which mimics a *Danais* or *Acræa* of the same region in the minutest particulars of form and colour. The *Danais tytia* of India has semi-transparent bluish wings, and a border of reddish-brown; this coloration is exactly reproduced in *Papilio agestor* and *Diadema nama*, all three insects frequently coming together in collections from Darjiling. In the Malay Archipelago the common and beautiful *Euplæa midamus* is so exactly mimicked by two rare species of *Papilio* that Mr Wallace generally mistook the latter at first for the ordinary insect. An immense number of other instances among the *Lepidoptera* have been quoted from other parts of the world.

Occasionally species of *Lepidoptera* also imitate insects of other orders. Many of them take on the appearance of bees or wasps, which are of course protected by their stings. Thus the *Sesiidæ* and *Ægeriidæ*, two families of diurnal moths, have species so like hymenopterous insects that they are known by such names as *apiformis*, *vespiforme*, *ichneumoniforme*, *sphegiforme*, and so forth. The British *sesia bombiliformis* closely resembles the humble bee; the *Sphecia craboniformis* is coloured like a hornet, and carries its wings in the same fashion. Some Indian *Lepidoptera* have the hind legs broad and densely hairy, so as exactly to imitate the brush-legged bees of the same country. Mr Belt mentions a Nicaraguan moth, *Pionia lycoides*, which closely mimics a distasteful coleopterous genus, *Calopteron*; and Professor Westwood pointed out that the resemblance to the beetle is still further increased in the moth by raised lines of scales running lengthwise down the thorax.

Among the *Coleoptera*, or beetles, and other orders, similar disguises are not uncommon. Mr Belt noticed species of *Hemiptera* and *Coleoptera*, as well as spiders, in Nicaragua, which exactly resemble stinging ants, and thus no doubt escape the attacks of birds. The genus *Calopteron* is mimicked by other beetles, as well as by the moth *Pionia*. In the same country, one of the *Hemiptera*, *Spiniger luteicornis*, has every part coloured like the hornet, *Priocnemis*, which it mimics; "in its vibrating coloured wing-cases it departs greatly from the normal character of the *Hemiptera*, and assumes that of the hornets." Mr Wallace mentions the longicorn beetle, *Cyclopeplus batesii*, which "differs totally in outward appearance from every one of its allies, having taken upon itself the exact shape and colouring of a globular *Corynomalus*, a little stinking beetle, with clubbed antennæ." *Erythroplatis corallifer*, another longicorn, almost exactly resembles *Cephalodonta spinipes*, one of the common South-American *Hispidæ*, which possesses a disagreeable secretion; and Mr Bates also found a totally different longicorn, *Streptolabis hispoides*, which resembles the same insect with equal minuteness. Some of the large tropical weevils have the elytra so hard that they cannot be pierced by a bird's beak; and these are mimicked by many other comparatively soft and eatable insects. In southern Brazil, *Acanthotritus dorsalis* closely resembles a *Curculio* of the hard genus *Heiliplus*; and Mr Bates found *Gymnocerus cratosomoides*, a longicorn, on the same tree with the hard weevil, *Cratosomus*, which it mimics. Other beetles resemble bees, wasps, and shielded bugs. Hairy caterpillars are well known to be distasteful to birds, and comparatively free from attack; and Mr Belt found a longicorn, *Desmiphora fasciculata*, covered with long brown and black hairs, and exactly mimicking some of the short, thick, woolly caterpillars common on the bushes around.

Amongst other orders, one of the most interesting cases is that of certain *Diptera* or two-winged flies which mimic wasps and bees. Sometimes this likeness only serves to protect the insect from attack, by inspiring fear of a sting. But there are also a number of parasitic flies whose larvæ feed upon the larvæ of bees, as in the British genus *Volucella*; and these exactly mimic the bees, so that they can enter the nests or hives to deposit their eggs without being detected even by the bees themselves. In every country where such flies occur they resemble the native bees of the district. Similarly, Mr Bates found a species of *Mantis* on the Amazons which exactly mimicked the white ants on which it fed. On the other hand, the defenceless species itself may mimic its persecutor, as in the case of several crickets, *Scaphura*, that exactly resemble various sand-wasps, and so escape the depredations of those cricket-killing enemies. Another cricket from the Philippine Islands, *Condylodera tricondyloides*, so closely copies a tiger-beetle, *Tricondyla*, that even Professor Westwood long retained it among that group in his cabinet,

and only slowly discovered his mistake. The cases here mentioned form but a small part of all those that have hitherto been observed and described in the insect world. They amount altogether to many hundreds.

Among plants, though included in the above definition for the sake of formal completeness, instances of true mimicry are rare or almost unknown. Perhaps the nearest approach to this phenomenon in the vegetal world is found in the resemblance borne by the dead-nettle, *Lamium album*, and a few other labiates, to the stinging nettle, *Urtica dioica* and *U. urens*. The true nettles are strikingly protected from animal foes by their stinging hairs; and the general appearance of the dead-nettle is sufficiently like them to prevent human beings from plucking it, and therefore probably to deter herbivorous mammals from eating it down. Mr Mansel Weale mentions another labiate, *Ajuga ophrydis*, of South Africa, which closely resembles an orchid, and may thus induce insects to fertilize its flowers. Mr Worthington Smith has found three rare British fungi, each accompanying common species which they closely resembled; and one of the common species possesses a bitter and nauseous taste; so that this would seem to be a case of true mimicry. Many diverse instances alleged by Mr A. W. Bennett, Dr Cooke, and others cannot be considered as genuine mimetic resemblances in the sense here laid down. They are mere coincidences or similar adaptations to similar needs; and the word ought to be applied strictly to such likenesses alone as benefit the organism in which they occur by causing it to be mistaken for another possessing some special advantage of its own.

The theoretical explanation of mimicry on evolutionary principles may best be considered in connexion with the general subject of protective coloration and variation in form, of which it is a very special case. There are two ways in which imitative colouring may benefit a species. It may help the members of the species to escape the notice of enemies, or it may help them to deceive prey. In the first case imitative hues enable the animal or plant to avoid being itself devoured; in the second case they enable it to devour others more easily, and so to secure a larger amount of food than less deceptively coloured compeers. In the former instance we must suppose that such individuals as did not possess the deceptive colouring have been discovered and destroyed by enemies with highly developed sight, while those which possessed it have survived. In the latter instance we must suppose that the individuals which have no protective colouring have failed to secure sufficient prey, through too readily betraying their presence, and that only those which possessed such colouring have become the parents of future generations. It is difficult, however, to separate these two cases, and in many instances the same colouring may aid a species both in escaping its peculiar enemies and in deceiving its peculiar prey. They may therefore most conveniently be considered together.

Colour is always liable to vary from individual to individual, as we see in the case of domesticated fowls, rabbits, dogs, and other animals, as well as in most cultivated flowers, wherever natural selection cannot act to keep the typical specific hues pure and true. But in a wild state certain conspicuous colours are sure to prove disadvantageous by betraying the individual, and these will sooner or later get weeded out, under certain circumstances, either through the action of enemies or by starvation resulting from the inability to escape the notice of prey. On the other hand, certain other colours are sure to benefit the individual by harmonizing with the tints of the environment and these will be spared by natural selection, so that the individuals possessing them will pair with one another, and will hand down their peculiarities to their descendants. In this way many species will acquire and retain a coloration that harmonizes with their environment as a whole or with some special part of it. The degree to which the protective coloration will be carried, however, must depend upon the sharpness of the senses in those other organisms which it is desirable to deceive. Large dominant herbivorous or frugivorous mammals or birds, with relatively few enemies, would not be benefited by protective coloration, and so they seldom exhibit it. The grasses or fruits on which they feed cannot make any attempt to escape them. But carnivores generally require to deceive their prey, and therefore a large number of them exhibit marked deceptive colouring. Still more especially do small defenceless birds or mammals need to escape the notice of the carnivores, and they accordingly very generally possess dull colours, because any variation in the direction of conspicuousness is certain to be promptly cut off. Above all, among insects, which are so largely the prey of birds, of reptiles, and of other animals possessing highly developed vision, protective coloration in one form or other is almost universal, except where a nauseous taste, hairy skin, or hard external coverings afford a different kind of protection. In every case the weeding out of ill-protected forms must depend upon the relative keenness of vision in the various enemies or of the prey, be they mammals, birds, reptiles, insects, or spiders. Hence the existence of protective coloring and of mimicry incidentally affords us valuable hints as to the perceptive faculties of the various classes against which each organism is thus unconsciously guarded.

Where the general aspect of the environment is most uniform, and where little but a vague impression of colour without individual form can be conveyed, the hues of animals are also usually uniform, to match their surroundings, and no special imitative adaptations of form occur. Thus, among the Arctic snows, a brown or black animal would immediately be perceived, and if defenceless at once devoured, while if a carnivore it would seldom or never approach unperceived near enough to its prey to effect a capture. Hence all such variations are at once repressed, and almost all Arctic animals, like the American polar hare, are pure white. Elsewhere bears are black or brown; in the polar region the native species is nearly indistinguishable from the snow in which it lives. Where the environment undergoes a regular change from season to season the colour of the fauna varies with it. The Arctic fox, the ermine, the alpine hare, the ptarmigan and many other birds, are all more or less brown among the brown hill-sides of autumn, and snow-white among the winter snows. Almost equally general is the sandy colour of deserts, though this, instead of being uniform, is slightly varied from grain to grain; and nearly all the birds, reptiles, and insects of Sahara exactly copy the sandy grey hue of the desert around them. Soles and other flat-fish (*Pleuronectidæ*) closely imitate the colour and speckled appearance of the sand on which they lie. The fishes and crustaceans which inhabit the sargasso weed are coloured the same yellow as the masses of algæ to which they cling. Aphides and many small leaf-eating caterpillars are bright green like the neighbouring foliage.

Where the environment is somewhat more diverse, the resemblance begins to show more specialized features. The lion, a large ground-cat of desert or rocky districts, is uniformly brown; but the tiger and other jungle-cats have perpendicular stripes which harmonize with the bamboos and brown grass of their native haunts; while the leopards, jaguars, and other tree-cats have ocellated spots which conceal them among the mingled light and shade of the forests. Large marine animals have the back black, because the water looks dark when seen from above, but their bellies are white, so as to harmonize with the colour of the surface when seen from below. Dr Weismann has shown that most edible unprotected caterpillars imitate the stripes and shades of the leaves among which they feed. Those which live upon grasses are longitudinally striped like the blades, those which live among small leaves are spotted and varied so as to resemble the distribution of light and shade in the bushes, and those which live upon large veined leaves with oblique ribs have oblique lines to harmonize with them. In some cases even the unripe berries are represented on the caterpillar by small reddish spots. A specialized form of this particular protective device is found in the chameleon, the chameleon-shrimp, many flat-fish, and some amphibians, all of which can vary their coloration to suit that of the surface on which they rest. The action is reflex, and ceases if the animal is blinded.

Where the environment is very varied, as in tropical forests, we find the greatest variety of colouring as well as actual imitation of particular forms; and the protective resemblances become at once closer and more common. Birds, reptiles, spiders, monkeys, and other active predaceous creatures are constantly hunting for insects and similar small prey amongst the fallen sticks or leaves; and among the most powerless classes of insects only those which very closely resemble specific objects in the environment can easily escape them. A gradual passage can be traced from the most general to the most special resemblances under such circumstances. Many forestine birds have a ground-tone of green in their plumage, which occurs nowhere but in the tropics. Some tree-lizards are green like the leaves on which they sit, others are marbled to resemble the bark where they lie in wait for their prey. Arboreal snakes often hang like lianas or other creepers. Insects which cling to the trunks of trees can seldom be distinguished from the bark. A Sumatran butterfly, *Kallima paralecta*, always settles on dry bushes among dead leaves, and can then hardly be perceived among the brown foliage, which it imitates even in the apparent blotches and mildew with which its wings are covered. The family of *Phasmidæ*, including the leaf and stick insects, carries such forms of imitation very far indeed. Most of them are large, soft, defenceless creatures; but some, like *Phyllium*, closely resemble green leaves, so as to be almost indistinguishable while feeding; and others exactly imitate short broken twigs of bamboo. Mr Wallace found one such insect, *Ceroxylus laceratus*, in Borneo,

apparently overgrown with a creeping moss or jungermannia; and Mr Belt discovered a larval form in Nicaragua whose body was prolonged into thin green filaments, precisely like the moss in which it lurked. In other instances the insect probably uses its disguise rather to deceive its prey than to escape its enemies. Sir Joseph Hooker believes that an Indian *Mantis* deludes the little creatures which .. . its food by its singular likeness to a leaf; while Sir Charles Dilke found one which had its head and fangs moulded into the deceptive appearance of an orchid, so that small flies were actually attracted in search of honey into its very jaws. Outside the class of insects, similar phenomena sometimes occur. Thus, according to Mr Bates, many showy little tropical spiders double themselves up at the base of leaf stalks so as to resemble flower buds, and thus delude the flies on which they prey. Even among the vertebrates Mr Belt mentions a green Nicaraguan lizard looking like the herbage by which it is surrounded, and decked with leaf-like expansions, which hide its predaceous nature from passing beetles or butterflies.

These last instances are divided from true mimicry by a very narrow line. But they differ in the fact that some vague object only in the general environment is simulated, not a particular protected species, as in genuine mimetic resemblance. If we allow, however, that natural selection can produce the white colour of Arctic animals, and the sandy hue of the sole and the flounder, it is easy enough to extend the same principle to the leaf-insect and the stick-insect, or even to real mimicry, as in the case of the *Leptalis* and the *Heliconidæ*. Certain *Phasmidæ* may at first have varied in the direction of green coloration, and these would naturally escape the eyes of birds more readily than their fellows. After the lapse of many generations, all the *Phasmidæ* of that special group would have become green, and the birds which preyed upon them would have learned in many cases to penetrate the disguise; for, as Mr Belt has observed, each fresh deceptive resemblance in the prey is sure to be followed by increased keenness of discrimination in the enemies of the species. At this stage the ordinary green *Phasmidæ* would often be killed, while only those which happened to approximate rudely in the venation of their wings to leaves would now escape the sharper and more experienced eyes of the birds. Thus step by step the disguise would become more and more perfect, only the best-protected of each generation escaping on the average, while all the worse-protected would be discovered and devoured. Given the usual luxuriance of tropical life, it is not difficult to understand how favourable variations might continually occur, until at length we get such perfect deceptions as those of the leaf-insects, the stick-insects, and the moss-grown larvæ.

The phenomena of true mimicry may be explained by a parallel genesis. Suppose, to begin with, a group of large and brilliant butterflies like the South-American *Heliconidæ*, protected by a nauseous taste and odour, and therefore never eaten by birds. To such insects slow flight and conspicuous hues are a positive protection, because they enable birds readily to discriminate them, and therefore prevent attacks, just as the banded body of the wasp and the hum of the bee prevent us from catching and killing them upon a window pane. Suppose, again, that in the same district there lives a widely different species of edible butterfly presenting some very slight and remote resemblance to the protected species. At first, no doubt, the resemblance will be merely an accidental one of general hue; it may even be so slight as to deceive nobody except upon the most distant and casual glance. Now, suppose these edible butterflies to be devoured in large quantities by birds, then a few of them may happen to gain safety by associating with the flocks of inedible butterflies which the birds refuse. After a time, even if the habit of consorting with the protected species becomes fixed in the race, the birds will begin to recognize the edible insects amongst the flocks, especially such as vary most in the opposite direction from the protected species. On the other hand, they will overlook such as vary most in the same direction as the inedible kind; and thus the least mimetic individuals will be destroyed, while the most mimetic will be left to pair with one another and to produce young, most of whom will present the like peculiarities. From generation to generation the birds will go on picking out every bad copy, and sparing all the best ones, till at last the two species become absolutely indistinguishable upon the wing. But the mimicry will never of course affect any but the most external and noticeable parts of the organism; it will be to the last a mere matter of colour, shape of wing, visible appearance of legs or antennæ, and so forth. The underlying structural differences will remain as great as ever, though externally masked by the deceptive resemblance in form and hue.

In like manner we may explain the genesis of the mimetic resemblance borne by *Volucella* to the humble bee. Suppose an undisguised fly to enter the bees' nest, it would be at once attacked and killed. But if it presented some very slight resemblance to the bee it might manage to lay its eggs undisturbed, and its larvæ would then be able to feed quietly upon the larvæ of the bee. With each new generation the more flimsy disguises would be more and more readily detected, and only those flies which varied most in the direction of resembling the bees would survive or lay their eggs in peace. On the other hand, those which actually succeeded would possess great advantages over their neighbours, because their larvæ would thus obtain a safe and certain supply of food, and be guaranteed the protection of the bees' nest. In this way the flies would at last, by constant survival of the best-adapted, come exactly to imitate the bees amongst which they lived.

The theory of the origin of mimetic forms thus briefly sketched out is due to Mr Bates and Mr Wallace, and it explains all the facts more fully than any other. It shows us, first, why the mimicking organism always imitates a specially protected species; secondly, why the two always inhabit the same district; thirdly, why the mimicking species is always much rarer than the species mimicked; fourthly, why the phenomenon is confined to a few groups only; and fifthly, why several different mimicking species often imitate the same protected form. It also accounts for the absence of mimicry amongst large or dominant animals, and its comparative commonness amongst small and defenceless kinds. And by affiliating the whole of the phenomena upon the general principles of protective colouring it reduces a seemingly strange and marvellous fact to a particular case of a well-known law.

Whatever theory be adopted, however, the facts and most of their implications remain the same. For, whether we suppose these imitative resemblances to be due to direct creative design or to survival of favourable variations, it is at least clear that the disguise subserves a function—that it is purposive and not accidental. Hence we may draw from the phenomena of mimicry certain important psychological implications. On the hypothesis of evolution, it is obvious that the mimicry can never go further than the senses of the creatures against whom the disguise is advantageous would naturally carry it; and even on the hypothesis of special design it is not likely that the imitation would be made more accurate than would be necessary for practical purposes of deception. There is much evidence in favour of this view. Mr B. T. Lowne, for example, who has carefully measured the curvature of the facets in the compound eyes of insects, upon which depends the minimum size of apprehensible objects, finds that the mimicry in the case of the flies parasitic upon bees' nests has proceeded just so far as the structure of the bee's eye would lead us to expect, and no further. In other words, so far as measurements of angular distance subtended can guide us, such a fly seems to be absolutely indistinguishable by a bee from one of his own species, within the limits of ordinary vision. The pictures cast upon the sensorium by the fly and by a brother bee are simply identical. In many other cases it can be shown that the mimicry seems specially intended to deceive the eyes of a particular class of animals; while there is no case of mimicry where the only enemies or prey consist of plants or eyeless animals. Naturally there can be no mimicry without a creature to deceive; the very conception implies an external nervous system to be acted upon, and to be acted upon deceptively. Thus mimicry in plants must have reference to the eyes of animals, in animals themselves to the eyes of one another. We may conclude, accordingly, that if a leaf-insect is green with faint violet-brown veins to the wings, exactly like a certain leaf, in order to deceive sundry tropical birds then those birds are capable of perceiving the forms and colours imitated to that particular degree. So the presence of mimicry in any group may guide us to a rough idea of the perceptive powers of those creatures whom the mimicry serves to deceive. The exact imitation of sand and coloured pebbles in the flat-fish is a fairly safe indication that the predaceous fish by whose selection they have been developed (through the weeding out of ill-protected variations) can pretty accurately distinguish form and colour. The long green pipe fish which cling around green sea-weed have probably acquired their existing hues to deceive the eyes of small sharks; the *Phyllopteryx eques*, a hippocampus which looks precisely like a piece of tangled and waving fucus (see figure, vol. xi. p. 852), has doubtless in the same way taken on its delusive likeness to the algæ among which it lives. So the cricket which resembles its foe the sand-wasp must have gained its present shape and hue by deceiving its enemy, and therefore it suggests the probability of highly developed vision on the part of the wasps. There seems every reason to believe that in many instances insects, spiders, and even lizards have developed mimetic or other deceptive resemblances in order to delude the eyes of insects; while in other cases the disguise has been unconsciously adopted to deceive fish, amphibians, reptiles, birds, and mammals. Moreover, we have some grounds for believing that the sense of colour is exceptionally strong in birds and in one or two insect orders; and the mimicry of colour seems to have proceeded to the greatest length amongst animals which are most exposed to the attacks of these classes, or which would find it advantageous to deceive them. It may be added that these same classes have been most effective in producing the bright hues of flowers and fruits, on Mr Darwin's hypothesis, or are at least in any case most intimately correlated with such vegetable structures as fertilizers of blossoms and dispersers of seed. Mimicry is thus to some extent a rough gauge of the perceptive faculties of the species deceived by it.

The vocal mimicry which occurs among certain birds, such as the mocking-bird, starling, parrot, and bullfinch, must of course be placed in a wholly different category from these biological cases. It is a direct volitional result, and it is mimicry in a literal not in a figurative sense. The faculty seems to be due to the play-instinct alone, and not to subserve any directly useful function. (G. A.)

MIMNERMUS, a Greek elegiac poet, born at Smyrna, lived about 600 B.C. His life fell in the troubled time when the old Greek city of Smyrna was struggling to maintain itself against the rising power of the Lydian kings. One of the extant fragments of his poems refers to the struggle and contrasts the present effeminacy of his countrymen with the bravery of those who had once defeated the Lydian king Gyges. The poet mentions in another fragment that he belonged to the stock of the Colophonians who had seized the Æolic Smyrna. But his most important poems were a set of elegies addressed to a flute-player named Nanno; they were collected in two books called after her name. Hermesianax mentions his love for Nanno, and implies that it was unfortunate. Only a few fragments of these poems have been preserved; and their soft melancholy tone and delicate language give some idea of the poet's character. His ideal is the sweet soft luxurious Ionian life, and he would enjoy it free from sorrow and die as soon as he could no longer enjoy it. Yet there is apparent some of the old stronger strain of character which in early time raised the Ionian cities to greatness, pride in the glories of his race and scorn for those that are unworthy of their fathers' renown. His experience of life was evidently sad; he felt that his country was gradually yielding to the enemy it had once defeated, and he knew that his own hopes were disappointed. The sun himself has endless toils from rising to setting and again from setting to rising. The life of man is as transitory as the leaves of spring, he says, referring to a passage in the popular epic poetry of Ionia (*Iliad*, vi. 146). He wishes to die in his sixtieth year, a wish to which Solon replied bidding him reconsider and rather long to die when he was eighty years old. Mimnermus was the first to make the elegiac verse, which had previously had more of the epic character, the vehicle for love-poetry, and to impart to it the colour of his own mind. He found the elegy devoted to objective themes; he made it subjective. He set his own poems to the music of the flute, and the poet Hipponax says that he used the melancholy νόμος Κραδίας. He bears the epithet Λιγυαστάδης, by which Solon addresses him. It is doubtful whether this epithet is peculiar to himself or whether it marks him as belonging to a musical and poetic family or school; it is evidently akin to the epithet λίγειαι Μοῦσαι.

MIMOSA. The *Mimoseæ* (so named from their mimicry of animal movements) form one of the three suborders of *Leguminosæ*, and are characterized by their (usually small) regular flowers and valvate corolla. Their 28 genera and 1100 species are arranged by Baillon in four series, of which the acacias (see ACACIA) and the true mimosas are the most important. They are distributed throughout almost all tropical and subtropical regions, the acacias preponderating in Australia and the true mimosas in America. The former are of considerable importance as sources of timber, gum, and tannin, but the latter are of much less economic value, though a few, like the talh (*M. ferruginea*) of Arabia and Central Africa, are important trees. Most are herbs or undershrubs, but some South-American species are tall woody climbers. They are often prickly. The roots of some Brazilian species are poisonous, and that of *M. pudica*, L., has irritating properties. *M. sensitiva* has been used in America in the treatment of fistula, &c., probably as an astringent. The mimosas, however, owe their interest and their extensive cultivation, partly to the beauty of their usually bipinnate foliage, but still more to the remarkable development in some species of the sleep movements manifested to some extent by most of the pinnate *Leguminosæ*, as well as many other (especially seedling) plants. In the so-called "sensitive plants" these movements not only take place under the influence of light and darkness, but can be easily excited by mechanical and other stimuli. When stimulated, say at the axis of one of the secondary petioles, the leaflets move upwards on each side until they meet, the movement being propagated centripetally. It may then be communicated to the leaflets of the other secondary petioles, which close (the petioles, too, converging), and thence to the main petiole, which sinks rapidly downwards towards the stem, the bending taking place at the pulvinus, or swollen base of the leafstalk. See BOTANY, vol. iv. p. 113, fig. 117. When shaken in any way, the leaves close and droop simultaneously, but if the agitation be continued, they reopen as if they had become accustomed to the shocks. The common sensitive plant of hot-houses is *M. pudica*, L., a native of tropical America but now naturalized in corresponding latitudes of Asia and Africa; but the hardly distinguishable *M. sensitiva* and others are also cultivated. The common wild sensitive plants of the United States are two species of the closely allied genus *Schrankia*.

MINDANAO, MINDORO. See PHILIPPINE ISLANDS.

MINDEN, the chief town of a district of the same name in Prussia, province of Westphalia, is situated about 22 miles to the west-south-west of Hanover, on the left bank of the Weser, which is spanned there by two bridges. The older parts of the town retain an old-fashioned appearance, with narrow and crooked streets; the modern suburbs occupy the site of the former fortifications. The most interesting building is the Roman Catholic cathedral, the tower of which, dating from the 11th century, illustrates the first step in the growth of the Gothic spire in Germany. The nave was erected at the end of the 13th century, and the choir in 1377–79. Among the other chief edifices are the old church of St Martin; the town-house, with a Gothic façade; the extensive court-house; and the Government offices, constructed, like many of the other buildings, of a peculiar veined brown sandstone found in the district. Minden contains a gymnasium and several hospitals, besides other charitable institutions. Its industries include linen and cotton weaving, dyeing, calico printing, and the manufacture of tobacco, leather, lamps, chicory, and chemicals. There is also some activity in the building of small craft. In 1881 107 vessels of an aggregate burden of 12,569 tons entered and cleared the river-harbour of Minden. The population in 1880 was 17,869.

Minden (Mindun, Mindo), apparently a trading place of some importance in the time of Charlemagne, was made the seat of a bishop by that monarch, and subsequently became a flourishing member of the Hanseatic League. In the 13th century it was surrounded with a wall. Punished by military occupation and a fine for its reception of the Reformation in 1547, Minden underwent similar trials in the Thirty Years' War and the wars of the French occupation. In 1648 the bishopric was converted into a secular principality under the elector of Brandenburg. From 1807 to 1814 Minden was included in the kingdom of Westphalia, and in the latter year it passed to Prussia. In 1816 the fortifications, which had been razed by Frederick the Great after the Seven Years' War, were restored and strengthened, and as a fortress of the second rank it remained the chief military place of Westphalia down to 1872, when the works were finally demolished. At Todtenhausen, 3 miles to the north of Minden, the allied English and German troops under the duke of Brunswick gained a decisive victory over the French in 1759. About 3 miles to the south of Minden is the so-called "Porta Westfalica," a narrow and picturesque defile by which the Weser quits the mountains and reaches the plain.

Minden is not to be confounded with the Hanoverian Münden, also sometimes written Minden (population 6355), at the confluence (*Mündung*) of the Werra and Fulda.

MINE. See MINING.

MINERALOGY

NATURAL objects which are homogeneous in their mass, and in which no parts formed for special purposes can be distinguished, are termed "minerals"; and the branch of natural science which treats of these is termed mineralogy. Minerals differ from the structures treated of in botany and zoology in the three following particulars. (1) They differ in the mode of their formation; this has been accomplished, not by assimilation of matter, producing growth from within, but by augmentation of bulk through accretion of particles from without. (2) Minerals are not heterogeneous. While the objects treated of in the other departments of natural history consist of beings possessed of life, and having parts which, being mutually dependent, cannot be separated from one another without a more or less complete destruction of the individual, the objects treated of under the department of mineralogy have so uniformly consistent an individuality that they are not destroyed by any separation of parts,—each portion or fragment possessing the same properties and the same composition as the whole. And (3), while those beings which are possessed of life have their component elements grouped into complexes, for the most part capable of more or less freedom of motion and susceptible of change, minerals have a constitution resulting from chemical attractions alone and an arrangement of their parts, under physical influences, which has resulted in rigidity and an absence of all tendency to change.

FORM OF MINERALS—CRYSTALLOGRAPHY.

Definition of a mineral.

The most precise definition of a mineral would be—an inorganic body possessed of a definite chemical composition, and usually of a regular geometric form. Of these, the second is in one respect the direct outcome of the first; while many of the most important physical properties possessed by minerals are outcomes of the second.

Both the geometric form and the composition of minerals are produced and modified under the influence of general laws.

Mineral bodies occur in the three physical conditions of solid, liquid, and gas. Those now found in the last two states are few in number, and are of altogether inferior interest to those which occur as solids; but there is reason to believe that the minerals we know as solids once existed in the liquid or gaseous state, and that their present structure was determined in the process of solidification. All bodies thus formed may be divided into two great classes:—

Amorphous bodies.

1. Amorphous bodies, or such as do not possess a definite and characteristic geometrical form. These (when transparent) refract light singly in every direction (except when under stress); they are equally easy or equally difficult to break in all directions; when broken they exhibit a conchoidal or an earthy fracture; they are equally hard throughout all their parts; they are equally elastic in all directions; they conduct heat with equal rapidity and in equal amount in all directions.

Crystals.

2. Crystalline bodies, or such as occur in definite geometrical forms bounded by flat surfaces. These present greater facilities of separation of their particles, or "cleavage," in certain directions lying in determinate planes than they do in others; most of them are neither equally hard nor equally elastic in all directions, conduct heat more rapidly in certain directions than they do in others, and, when transparent, refract light doubly except in certain directions.

Mineral bodies are found in both of the above classes; and the same mineral body may occur in both the amorphous and the crystalline condition. This is seen in the piece of gold shown in fig. 1, where the upper portion has a sharply angular and a well-defined shape, while the lower presents curvilinear and rugged outlines, similar to one another in no part. Under favouring circumstances, it is possible that every substance whose composition is capable of being represented by a definite chemical formula—*i.e.*, which has an unvarying composition—may be capable of assuming a definite crystalline form.

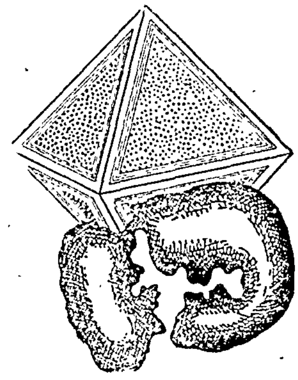


Fig. 1.

Size of crystals.

Size and Form of Crystals.—They are of every size from over a yard in diameter to mere specks requiring a high power of the microscope to reveal their existence. Beryls have been obtained in America more than 4 feet in length by 2½ in thickness, weighing 2½ tons. Equally large crystals of apatite have been found in Canada. There is a rock crystal at Milan 3¼ feet long by 5½ in circumference, weighing 870 lb. The highest perfection of form, and hence of other properties, is only found, however, in crystals of moderate or of small size.

Variety of form.

Variety of Form, and Constancy of Form.—The same mineral may be found in different localities, or sometimes in the same locality, exhibiting an almost endless variety of forms. Calc-spar occurs at a Scottish locality in acicular pyramidal crystals of which the length may be ten or more times as great as the width (fig. 2); in flat plates as thin as paper, in which the length is not the hundredth part of the width; also in prisms, pyramids, and rhombohedra, which at first sight (as in figs. 3, 4) seem

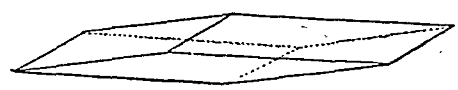


Fig. 3.

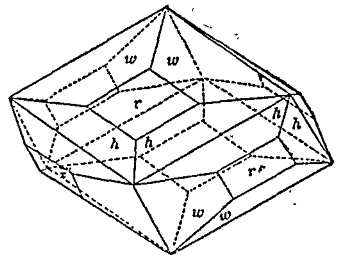


Fig. 4.

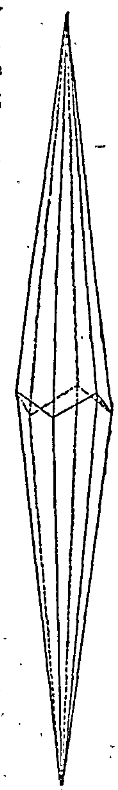


Fig. 2.

destitute of any relationship to each other. This substance has elsewhere been noted in several hundred forms. The minerals fluorite, pyrite, and baryte have each been observed in over a hundred diverse forms. Nevertheless, however great the number, all the forms, in the case of each mineral, may be reduced or referred to a single type, by the simple process of examining its internal structure or the mode of arrangement of its molecules. This is

Relation to parent form.

accomplished in two ways—(1) by finding the weak joints in that arrangement, through splitting the crystal, and (2) by measuring the angular inclination of the outside surfaces which bound the form and, from these measurements, by simple mathematical laws, arriving at what has been termed its "primitive" or simplest form.

Invariability of angles.

As regards the mere recognition of a substance, such measurement in itself suffices,—the angular inclination, if the same surfaces be measured, being unvarying in each species. It can, moreover, be shown that the possible range of external variety of form is governed by fixed mathematical laws, which determine precisely what crystalline forms are or may be produced for each species. Comparatively few of these actually occur in nature; but crystallographic laws can point out the range of those which can possibly occur, can delineate them even before they are found, and can in all cases show the relationship which subsists between them and the simple or fundamental form from which or out of which they all originate. It must be observed that in crystalline bodies the internal structure—that is, the arrangement of the molecules—is as regular in an outwardly shapeless mass as in the modelled crystal which presents itself as a perfect whole.

Properties and parts of crystals.

Definitions of Crystals, and their Members or Parts.—A crystal is a symmetrical solid, either opaque or transparent, contained within surfaces which theoretically are flat, and of a perfect polish, but which are actually frequently curved, striated, or pitted. These surfaces are called "planes," or "faces." The external planes of a crystal are called its "natural planes"; the flat surfaces obtained by splitting a crystal are called its "cleavage planes." The intersections of the bounding planes are called "edges," and planes are said to be similar when their corresponding edges are proportional and their corresponding angles equal. Crystals bounded by equal and similar faces are termed "simple forms." The cube, bounded by six equal squares, the octahedron, bounded by eight equilateral triangles, and the rhombohedron, bounded by six equal rhombs, are thus simple forms. Crystals of which the faces are not all equal and similar are termed compound forms, or "combinations," being regarded as produced by the union or combination of two or more simple forms. Edges are termed rectangular, obtuse, or acute, according as the angle at which the faces which form the edge meet is equal to, or greater or less than, a right angle. Edges are similar when the planes by the intersection of which they are formed are respectively equal and equally inclined to one another; otherwise they are unlike or dissimilar.

Interferences.

When a figure is bounded by only one set of planes, it is said to be "developed." When an edge is cut off by a new plane, it is said to be "replaced"; when cut off by a plane which forms an equal angle with each of the original faces which formed the edge, it is said to be "truncated." When an edge is cut off by two new faces equally inclined to the two original faces respectively, it is said to be "bevelled." When a solid angle is cut off by a new face which forms equal angles with all the faces which went to form the solid angle, it is said to be truncated.

Axes.

In classifying crystals and studying their properties, it is found convenient to introduce certain imaginary lines called "axes." Axes are imaginary lines connecting points in the crystal which are diametrically opposite,—such as the centres of opposite faces, the apices of opposite solid angles, the centres of opposite edges. Different sets of axes may thus be drawn through the same crystal; but there is always one set, usually of three, but in one special class of crystals of four, axes, by reference to which the geometrical and physical properties of a crystal can be most simply explained. These axes intersect one another, either at right angles, producing "orthometric" forms, or at oblique angles, producing "clinometric" forms. The axes may be all equal, or only two equal, or all unequal.

"Positioning" of crystals.

There is a definite conventional position in which for purposes of description a crystal is always supposed to be held. With reference to this position one of the axes,—that which is erect or most erect,—is termed the "vertical," and the others the "lateral." The planes in which any two of the axes lie are called the "axial" or "diametral planes,"—sometimes "sections." By these the space around the centre is divided into "sectants." If there are, as is generally the case, only two lateral axes, the space is divided into eight sectants, or octants; but, if there are three lateral axes, it is divided into twelve sectants.

Primitive forms

Primitive Forms of Crystals.—If we attempt to arrive, through a study of the internal structure of crystals, as evidenced by directions of weakness of cohesion, at the total number of primitive or parent forms which can exist, we find that there are thirteen such forms and no more.

Nine of these may be regarded as prisms standing upon a base, three as octahedra standing upon a solid angle; and there is one twelve-sided figure, or dodecahedron.

Prisms

Prisms.—Of the prisms eight have a four-sided base.

If the base is square and the prism stands erect—that is, if its sides or lateral planes, as they are called, are perpendicular to the base—the form is termed a "right square prism" (fig. 6). In this the four lateral planes are rectangular and equal; they may be either oblong or square; in the latter case the form is the "cube" (fig. 5). When the base is a rectangle instead of a square, the form is a "right rectangular prism" (fig. 7). In each of the

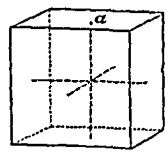


Fig. 5.

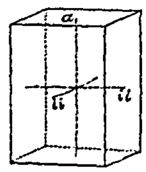


Fig. 6.

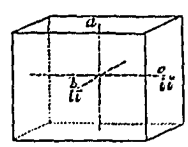


Fig. 7.

above three forms the edges are twelve in number. In the cube all the edges are equal. In the square prism the lateral edges are all equal, but are different from the four equal edges of the base. In the rectangular prism, two at each base differ in length from the other two, while both differ from the lateral; hence there are here three sets of edges, four in each. In each of the three forms, however, the solid angles are eight in number, all equal, and each enclosed by three right angles.

When the base is a rhombus, and the prism stands erect, the form is a "right rhombic prism" (fig. 8). Two of the angles in the base being here acute and two obtuse, two of the solid angles corresponding each with each must differ from the others. So also must two of the lateral angles be acute and two obtuse. The four lateral faces are equal.

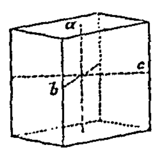


Fig. 8.

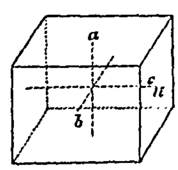


Fig. 9.

When the base is a rhomboid, and the prism stands erect, it is only the opposite lateral faces that can be equal. The form is called a "right rhomboidal prism" (fig. 9).

When the base is a rhombus, but the prism stands obliquely on its base, the form is called an "oblique rhombic prism" (fig. 10). Here the basal edges of the lateral planes are all equal in length, but on account of the inclination of the prism the angles which these edges form with the lateral edges of the lateral planes are two acute and two obtuse.

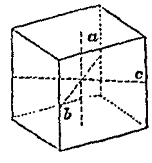


Fig. 10.

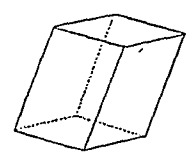


Fig. 11.

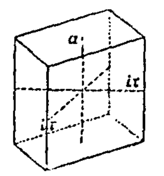


Fig. 12.

If all the edges of an oblique rhombic prism are equal in length to the breadth of the base, and if the lateral planes are rhombi equal in all respects to the basal, the form is called a "rhombohedron" (fig. 11). This is included within six equal planes, like

the cube, but these planes have oblique angles. The rhombohedron thus bears the same relation to the oblique rhombic prism which the cube does to the right square prism. Of the eight solid angles of a rhombohedron only two are contained by three equal plane angles, and these two "apices," as they may be called, are opposite one another. According as the apices are acute or obtuse, we have an acute or obtuse rhombohedron.

When the base of an oblique prism is a rhomboid, the prism becomes an "oblique rhomboidal prism" (fig. 12). In this form, only diagonally opposite edges are similar, as regards equality of length and the value of the included angle. Only opposite solid angles are equal, as are also the opposite and parallel faces.

A right prism may have an equilateral six-sided base; it is then called an "hexagonal prism." This form may be developed in two positions relatively to each other,—one in which the transverse axes pass from the centres of opposite faces (fig. 13), the other in which they pass from the centres of opposite edges of the planes (fig. 14). The faces of the one set mutually truncate the edges of the other. If a rhombohedron be positioned so as to rest upon one of its apices, the faces of one hexagonal prism would truncate the lateral *edges* of the rhombohedron, while the faces of the other hexagonal prism would truncate its lateral *solid angles*. Hexagonal prisms may be longer or shorter than the width of their bases. The interfacial lateral angles are 120°. The angle between the lateral and terminal faces is 90°.

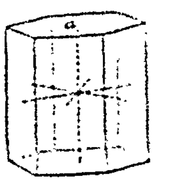


Fig. 13.

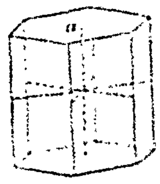


Fig. 14.

Octahedra.

Octahedra.—The planes of these eight-faced solids are triangular, and they may be regarded as made up of two four-sided pyramids applied to each other, base to base. They are always positioned so that they stand upon a solid angle with the "basal plane"—that is, the plane which is the common base of the two pyramids—horizontal. In the primitive forms now under consideration the vertices of the two pyramids will in this position be vertically above and below the centre of the base. The upper and lower solid angles are then termed the "vertical solid angles," and the four lateral solid angles are called the basal solid angles.

There are three octahedrons. In the "regular" octahedron (fig. 15) the base is a square, and the eight faces are equilateral triangles of equal size. There are twelve edges, which are all equal. The faces incline to each other at an angle of 109° 28' 16", and have the plane angles all 60°. There are six equal solid angles. When the base of the octahedron is square, but the other edges, although

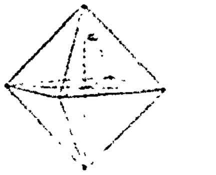


Fig. 15.

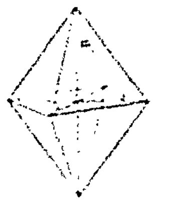


Fig. 16.

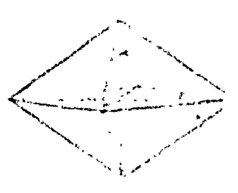


Fig. 17.

equal to one another, are either longer or shorter than the edges of the base, the form is a "right square octahedron" (fig. 16). In this the faces are isosceles triangles, the equal angles being at the basal edge of the planes. These basal edges are equal and similar, but differ in length and in angles from the eight equal pyramidal edges. When the base of an octahedron is a rhombus, it is called a "right rhombic octahedron" (fig. 17).

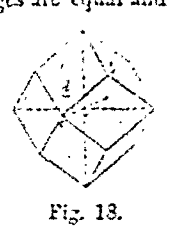


Fig. 18.

Dodecahedron.

Dodecahedron.—This (fig. 18) has each of its twelve faces a rhombus. It is, like the cube and the octahedron, a solid which is symmetrical. The interfacial angles are all 120°, the plane angles are 109° 28' 16" and 70° 31' 44". The edges are twenty-four, and similar. There are fourteen solid angles, of which six are formed each by the meeting of four acute plane angles, and eight by the meeting of three obtuse plane angles.

Determination of parent forms.

It has been said that the above simple forms were arrived at through a study of the internal structure of crystals, chiefly as disclosed by cleavage. Inasmuch, however, as there are some minerals which cleave in only one direction, and many which cannot be cleaved in any direction, this method of investigation fails. Its employment, moreover, frequently led to conflicting or embarrassing results. A conflicting result is when a substance has more than one set of cleavages,—that is, splits up in directions which would result in the production of more than one of the above primary or simple forms. Thus the mineral fluorite occurs with much the greatest frequency in the form of the cube, and it might very consistently be held that its frequent occurrence in this form was a clear natural indication that the cube was the primary or simplest form of fluorite; but it splits up into an octahedron. Galena crystallizes frequently in the form of the octahedron; yet to cleavage galena yields a cubic primary form. It might be conceived that there had been, in each case, some special tendency to assume the cubic form and the octahedral form; but one and the same piece of rock may bear on its surface cubic crystals of fluor and octahedral crystals of galena,—each of the minerals having here assumed the primitive cleavage form of the other in preference to its own. The mineral blende crystallizes not unfrequently in octahedra, which yield the dodecahedron on cleavage. Fluor crystallizes in dodecahedra, yet yields the octahedron to cleavage. Argyrite crystallizes in cubes and in octahedra, but yields the dodecahedron on cleavage. Pyrite crystallizes in cubes, octahedra, and dodecahedra, and yields both the cube and the octahedron on cleavage.

These are most embarrassing results, but they clearly indicate so intimate a relationship to subsist between three of the above simple forms that it is obvious that one alone would serve as a type form for representing the others. The selection of that one should be based upon grounds of most eminent simplicity, and this again is to be arrived at by a consideration of the smallness of number of parts, *i.e.*, of faces, edges, and solid angles. In such a consideration we find that the dodecahedron, with its higher number of each of these, at once gives place. The cube has six faces, the octahedron eight; simplicity here is in favour of the cube. The cube has twelve edges, the octahedron has twelve; in this respect they are equal. The cube has eight solid angles, the octahedron six; here the greater simplicity is on the side of the octahedron. So that this method of adjudicating by simplicity fails, and we are thrown back upon the relationships which may be unfolded through a consideration of the other elements of crystals,—their axes.

Systems of Crystals and Laws of Crystallization.

This consideration led, first, to the remarkable discovery that several of the above primary forms are mere modifications of each other, and ultimately showed that all crystals found in nature may be referred to six systems, based on certain relations of their axes, and that every face which could occur upon a crystal bears a definite and simple relation, in position and in angular inclination, to these axes. Relation of faces to axes.

As regards mere geometric measurement, there are several directions in which axes may with nearly equal advantage be projected. For example, in the cube (fig. 19) they may be drawn from the centres of opposite faces, as lettered O; or from opposite solid angles, as lettered C; or from the centres of opposite edges, as lettered D. There is abundance of evidence that each of these directions must be regarded as lines of dominant accretion of molecules. Axes directions of dominant accretion.

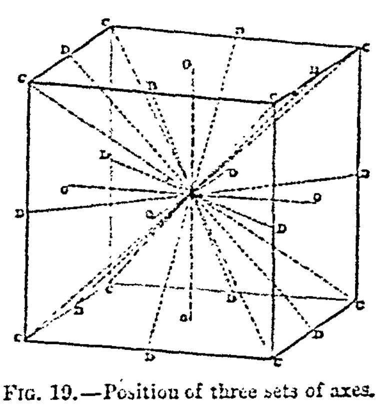


Fig. 19.—Position of three sets of axes.

But the accretion may be not only dominant but overwhelmingly so in one only of these directions in certain cases, or existent along one set of axes alone in certain others. In a specimen of native silver from Alva in Scotland (fig. 20), along O this is so much the case that the concreting molecules have done little more than delineate the form of an octahedron, and this they have only been able to do by

aggregating themselves in lines of minute crystals of the very shape of which they were projecting the skeleton form. Moreover, a polar aggregation at the terminal ends of these octahedral axes is here shown by the amount of concreting and crystallizing

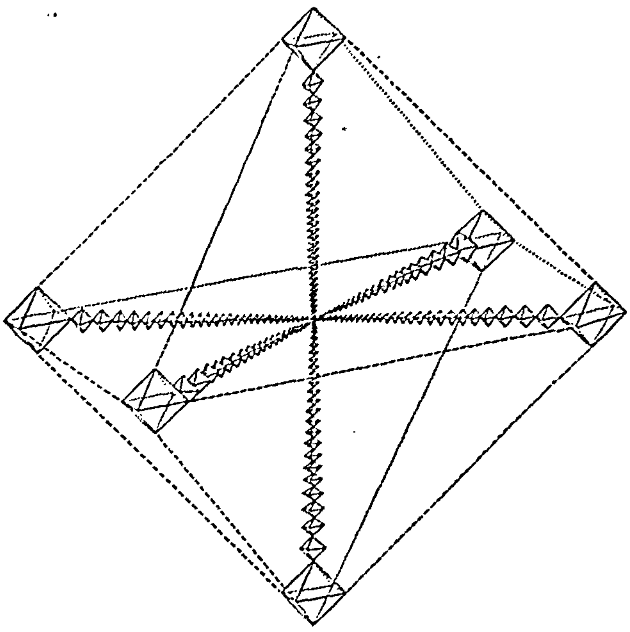


Fig. 20.

material being larger at the terminations of these axes than elsewhere. In the hollow-faced cube again (fig. 21), an aggregation of molecules in the direction of the lines D and C has filled the edges and solid angles, while none have been deposited along O.

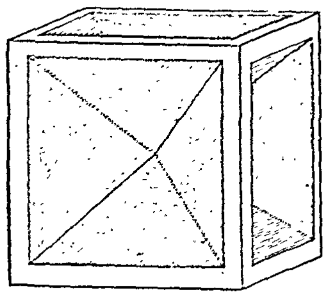


Fig. 21.

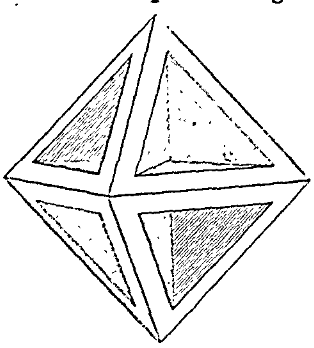


Fig. 22.

This occurs in crystals of salt. In the hollow-faced octahedron, again (fig. 22), there has been no deposition of matter along the line C. Cuprite often shows this form; and it as frequently occurs in hollow-faced dodecahedra, wherein the vacuity is in the direction of D.

In the specimen of pyrite from Elba (fig. 23), a deposition along D and C would ultimately have erected the scaffolding of a hollow cube, in twelve lines of minute combinations of the cube and octahedron. Such directional arrangements may, moreover, not only be intermittent but often alternate. The pyrite from Traversella (fig. 24) is an illustration of the first. A large pentagonal dodecahedron having been completed, a new accession of material has been attached, not uniformly spread over the pre-existent crystal, to enlarge it, but locally arranged, in equal amount, at the poles of O. But here the special method of the arrangement has determined the formation of a number of small crystals of the same form as that originally projected.

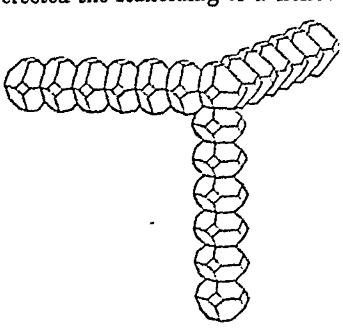


Fig. 23.

An alternation, as it were, in plan is shown in such a crystal of calcite as that in fig. 25. Here a scalenohedron is seen in the centre of the figure; then a rhombohedron has been perched upon its summit, and lastly both have been sheathed in a six-sided prism with trihedral summits. Different as these three forms are, it is found that they all here stand in a definite position one to the other; that definite position is the relation which they bear to one of the sets of axes, and this set may be assigned, not only to all the three crystals here combined, but also to all the crystals belonging to the same mineral, wherever occurring. This general applicability constitutes one of the respects in which one special set of axes is, in each of the systems, preferred to the others.

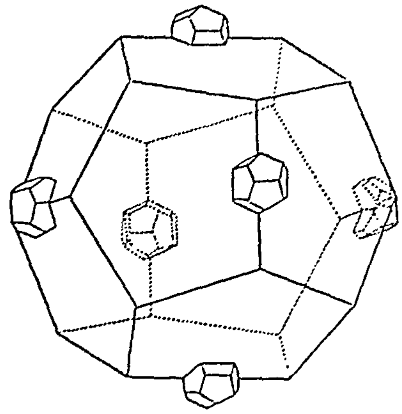


Fig. 24.

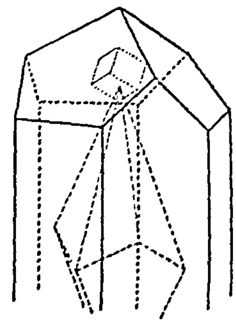


Fig. 25.

Another respect is the intensity with which the molecules cohere in the different parts of the crystal, as referred to these axes, and the resultant different hardness of certain parts of crystals. It will be afterwards found that this obtains in a very limited manner in the crystals which belong to the first of the following systems, on account of its regularity and sameness as a whole. It may be laid down as a general rule that the edges of crystals are harder than the centres of their faces, and the solid angles harder than the edges. This is markedly the case in the diamond. But, apart from this, there is no distinctive hardness in any one part, side, or end of the crystals of the first system. It is otherwise with the crystals which fall to be considered in all the other systems. So different is the hardness of the various portions of these, so diverse the appearance of their parts in lustre, colour, polish, &c., so varying the amount of the recoil of these when struck, so unequal their power of conducting heat, so dissimilar their power of resisting the agencies of decay, and so irreconcilable their action upon transmitted light, that we cannot but conclude that the molecules which build them up are packed with greater force, if not in greater number, in certain directions in preference to others. There thus remains no question that these nature-indicated sets of axes are those along which there has been a specially selective or "polar" arrangement.

Coherence of particles not equal in all directions.

The six systems are founded upon the relationships of the axes in number, in length, and in angular inclination. All crystals may be divided into "orthometric" or erect forms and "clinometric" or inclined forms; and in similar manner may the systems be, through a consideration of the relative lengths of their axes, divided into three classes. In the first, or most regular, of these the axes are all equal, that is, they are of one length; in the second there is one axis which differs in length from the others, and therefore they are of two lengths; while in the third the axes are all unequal, and therefore they are of three lengths. Of the six systems one belongs to the first class, two to the second, and three to the third. Hence they are thus classed:—

Systems of crystals.

Monometric.	*Dimetric.*	*Trimetric.*
Cubic.	Tetragonal.	Right Prismatic.
	Hexagonal.	Oblique Prismatic.
		Anorthic.

Though the grouping of the systems into three classes in virtue of axial dimensions is markedly borne out by optical and other properties, yet it is altogether insufficient for determining the relationships of the myriad forms in which bodies crystallize. Such knowledge is only attained by combining the consideration of axial length with axial inclination; and it is through a due regard of both of these that the six systems are instituted.

The above table may be read in two different ways,—either across or consecutively up and down the page. The six systems may be treated of in either of these ways;

and there are certain advantages in considering them at least first by the former method.

We consider first, as the more essential, the relative lengths of the axes, and, secondly, the angular inclination of these.

1. In the cubic system the axes are all equal, and all intersect at right angles. Here is the most perfect simplicity, and the most perfect regularity.

2. In the tetragonal system two only of the axes are equal; but all still intersect at right angles. Here is a departure from simplicity as regards the length of one axis, but no departure as regards the angular inclination.

3. In the right prismatic system none of the axes are equal, but all still intersect at right angles. Here is total loss of regularity in the first particular, but still none in the second.

4. In the oblique prismatic system none of the axes are equal, and only two intersect at right angles. Here there is again a total loss of simplicity in the first particular, and a certain amount of departure from it in the second.

5. In the anorthic system none of the axes are equal, and none of them intersect at right angles,—so that here, as expressed by the name, there is a total departure from regularity in both particulars.

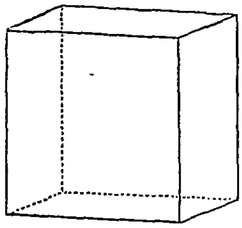


Fig. 26.

6. The hexagonal system is anomalous in relation to this mode of consideration. It is regarded as having four axes, three of which lie in one plane, parallel to the base, and intersect each other at equal angles (necessarily angles of 60°). The fourth axis intersects these at right angles, and may be longer, shorter, or equal to them. This system is generally considered after the tetragonal system, as having one axis which differs in length from the others, and only one which cuts the others at right angles. By some a rhombohedron is considered as the primary of this system; it then comes to have three axes, all equal, but none intersecting at right angles.

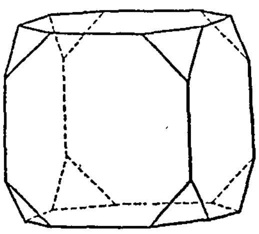


Fig. 27.

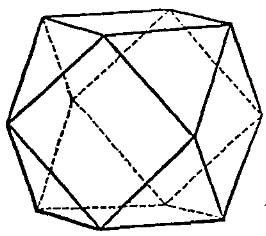


Fig. 28.

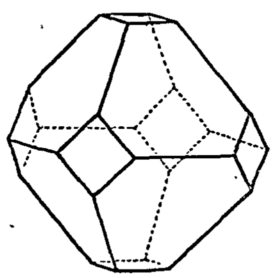


Fig. 29.

Unique axis made vertical.

In considering these systems, or in describing the form of a crystal, the vertical or erect axis is named the principal axis of the figure, and that axis is chosen as the vertical which is the only one of its kind. In the cubic system there is no such axis, so that any one may be chosen as the vertical.

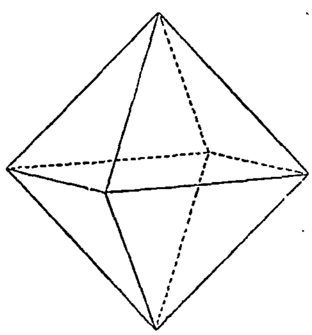


Fig. 30.

It will be convenient, before proceeding to the consideration of the laws of crystallography and the combinations of forms,—especially in view of the terminology that must be employed in illustrating those general aspects of the subject,—to give an outline of one of the six systems here. For this preliminary description the cubic system, as the simplest and most regular, naturally suggests itself as the most suitable.

Cubic system.

I. *The Cubic System.*—Here the axes are all equal, and all intersect at right angles. The "cube" (fig. 26), "octahedron" (fig. 30), and "rhombic dodecahedron" (fig. 33), which are here included, are alike in their perfect symmetry; the height, length, and breadth are equal; and their axes are equal, and are rectangular in their intersections.

Relations of simple forms.

In the cube (fig. 5) these axes connect the centres of opposite faces; in the octahedron (fig. 15) the apices of opposite solid angles; in the dodecahedron (fig. 18) the apices of opposite acute solid angles. The relation of these forms to each other, and the correspondence in their axes, will be made manifest through a consideration of the transition between the forms. If a cube be projected with the axes in the above position, or if a model of it in any sectile material be employed, and if the eight angles are sliced off evenly, keeping the planes thus formed equally inclined to the original faces, we first obtain the form in fig. 27, then that in fig. 28 and fig. 29, and finally a regular octahedron (fig. 30); and the last disappearing point of each face of the cube is the apex of each solid angle of the octahedron. Hence the axes of the former, being in no way displaced, necessarily connect the apices of the solid angles of the latter. By cutting off as evenly the twelve edges of another cube, the knife being equally inclined to the faces, we have the form in fig. 31, then fig. 32, and finally the rhombic dodecahedron (fig. 33), with the axes of the cube connecting the acute angles of the new form. These forms are thus mutually derivable. Moreover, they are often presented by the same mineral species, as is exemplified in galena, pyrites, and the diamond.

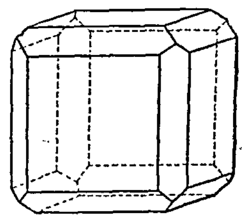


Fig. 31.

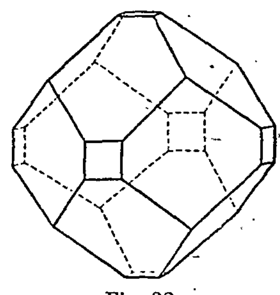


Fig. 32.

The process may be reversed, and the cube made from the octahedron, as will be readily understood from a comparison, in reverse order, of figs. 26 to 30. Or the cube may be similarly derived from the dodecahedron, as seen by inspecting figs. 33, 32, 31, 26.

The octahedron also is changed to a rhombic dodecahedron by removing its twelve edges (figs. 34, 35), and continuing the removal till the original faces are obliterated, thus producing the dodecahedron.

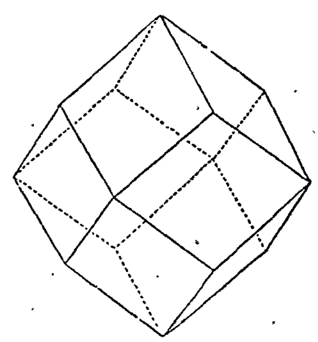


Fig. 33.

It will be observed that throughout all these changes the position of the axes, as determinants of dimensions, need not be altered,—that, in fact, one set of axes has served for all the forms.

The relationships of the principal forms of this system being thus disclosed, the forms themselves have next to be considered.

Parts of the cube. The cube (fig. 26) is bounded by six equal squares, has twelve edges formed by faces meeting at 90°, and eight solid trigonal angles. The axes are taken as joining the centres of each two opposite faces. Examples are hallite, galena, and fluor.

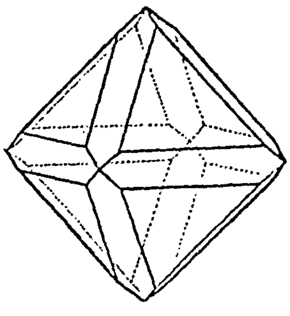


Fig. 34.

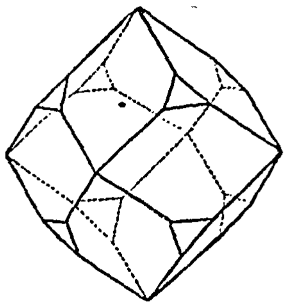


Fig. 35.

Octahedron. The octahedron (fig. 30), bounded by eight equilateral triangles, has twelve equal edges with planes meeting at 109° 28′ 16″, and six tetragonal angles. The principal axes join the opposite solid angles. Examples: magnetite, gold, cuprite.

Dodecahedron. The rhombic dodecahedron (fig. 33) is bounded by twelve equal and similar rhombi, has twenty-four equal edges of 120°, and has six tetragonal and eight trigonal angles. Each of the principal axes joins two opposite tetragonal angles. Examples: garnet, cuprite, blende.

Tetrakishexahedron. The tetrakishexahedrons (figs. 36, 37, 38, varieties of icositetrahedron) are bounded by twenty-four isosceles triangles, placed so as to form four-sided pyramids on the faces of the cube, arranged in six groups of four each. They have twelve longer edges, which correspond to those of the primitive or inscribed cube, and twenty-four shorter edges placed over each of its faces. The angles are eight hexagonal and six tetragonal, the latter joined two and two by the principal axes. Examples: fluorite, gold. This form varies much in general aspect. The four-sided pyramid which rests on the edges of each face of the cube may be so low as almost to fall into it (fig. 36); or it may rise so high that each side forms a level surface with that which is adjacent to it upon the nearest cubic face (fig. 38). In the latter case the form has become the rhombic dodecahedron; so that the more or less acute varieties of the form are but stages of a passage of the cube into the latter figure, through an increasing accretion of matter in the lines of the axes of the cube. This is termed a "transition by increment."

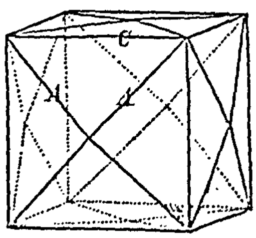


Fig. 36.

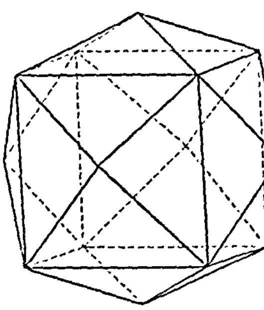


Fig. 37.

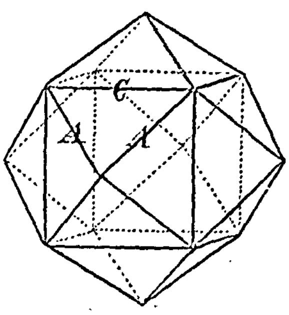


Fig. 38.

Triakisoctahedron. The triakisoctahedrons, fig. 39 (variety of icositetrahedron, fig. 40), are bounded by twenty-four isosceles triangles, in eight groups of three, arranged as pyramids on the edges of the faces of the octahedron. Like the previous form they vary in general aspect, the variation here being from the octahedron on one side to the rhombic dodecahedron on the other; while the increased accretion here is in the direction of lines joining the centres of the faces of the octahedron or the solid angles of the cube. The passage of the forms is similar to that illustrated in the last-considered form. The edges are twelve longer, corresponding with those of the inscribed octahedron, and twenty-four shorter, three and three over each of the faces. The angles are eight trigonal and six ditetragonal (formed by eight faces), the latter angles joined two and two by the principal axes. Examples: galena, diamond.

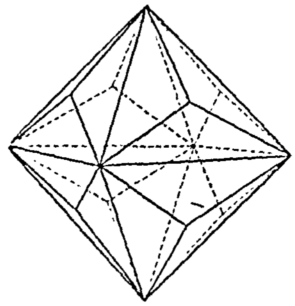


Fig. 39.

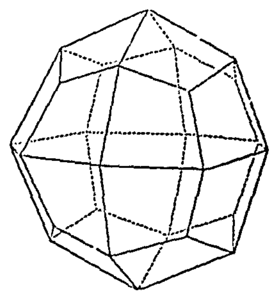


Fig. 40.

Icositetrahedron. The icositetrahedrons (fig. 40) are bounded by twenty-four deltoids. This form varies from the octahedron to the cube, sometimes approaching the former and sometimes the latter in general aspect. A *four-sided pyramid* rests on the angles of the faces of the cube. When increased accretion takes place along the cubic axes, an octahedron results. When it is along lines joining the solid angles of the cube, that form itself results. The edges are twenty-four longer and twenty-four shorter. The solid angles are six tetragonal joined by the principal axes, eight trigonal, and twelve rhombic or tetragonal with unequal angles. Examples: analcime, garnet.

Hexakisoctahedron. The hexakisoctahedrons (fig. 41), bounded by forty-eight scalene triangles, vary much in general aspect, approaching more or less to all the preceding forms, into all of which they may pass; but most frequently they have the faces arranged either in six groups of eight on the faces of the cube, or eight of six on the faces of the octahedron, or twelve of four on the faces of the dodecahedron. There are twenty-four long edges, often corresponding to those of the rhombic dodecahedron or bisecting the long diagonal of the trapezohedron, twenty-four intermediate edges lying in pairs over each edge of the inscribed octahedron, and twenty-four short edges in pairs over the edges of the inscribed cube. There are six ditetragonal angles joined by the principal axes, eight hexagonal, and twelve rhombic angles. Examples: diamond, fluorite.

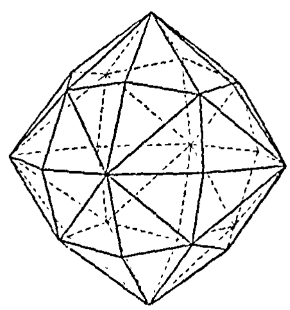


Fig. 41.

Laws of crystallography. *General Laws of Crystallography.*—The seven forms of crystals now described are related to each other in the most intimate manner. This will appear more distinctly from the account which is to follow of the mode of derivation of the forms, with which is conjoined an explanation of the crystallographic signs or symbols by which they are designated. These symbols were introduced by Naumann, in the belief that they not only mark the forms in a greatly abbreviated manner, but also exhibit the relations of the forms and combinations in a way which words could hardly accomplish. In order to follow out this

derivation of forms, it is necessary to state briefly the following laws, which have been established in crystallography. It is to be remembered that these laws apply, not merely to the cubic system just described, but to all the systems.

Invariability of angles.

1. *The Law of the Invariability of the Angles of Crystals*, which was established by Romé de l'Isle, may be thus stated:—the angles of inclination of the faces of a crystal are constant, however unequally the faces may be developed. The corresponding angles of different crystalline specimens of the same body do not, however, always absolutely agree. Differences have been found, amounting sometimes even to 10′.

Symmetry.

2. *The Law of Symmetry*, discovered by Haüy, may be thus expressed:—(1) similar parts of crystals—faces, edges, angles, and consequently axes—are all modified in the same manner, and dissimilar parts are modified separately or differently; (2) the modifications produce the same effect on the faces or edges which form the modified part, when they are equal; when they are not equal, they produce a different effect. That is, if an edge be truncated or bevelled, every similar edge will be similarly truncated or bevelled; if an angle be truncated or acuminated, every similar angle will be similarly truncated or acuminated; and consequently every similar axis will be equally affected by the modifications. Thus the cube has eight similar angles and twelve similar edges. In the physical production of the cube, if one of the angles or edges be modified, all will be similarly modified. This, which is the most important law of crystallography, is, however, subject to an exception which was fully formulated by Weiss. The law was—all the similar parts of crystals, faces, edges, angles, and consequently axes, are modified at the same time and in the same manner; the forms resulting from this law are termed "holohedral." The exception is that half of them or one-fourth of them only may be similarly modified. When only half of the similar parts are modified, we get the "hemihedral" forms; when one-fourth only are modified, which occurs only rarely, we get "tetartohedral" forms.

Parallelism of faces.

3. *The Law of the Parallelism of the Faces of a Crystal*, discovered by Romé de l'Isle, may be expressed as follows:—every face of a crystal has a similar face parallel to it; or every figure is bounded by pairs of parallel faces (with the exception of certain hemihedral forms).

Zones.

4. *The Law of Zones*, first established by Weiss, may be thus enunciated:—the lines in which several faces of a crystal intersect each other (or would do so if they were produced until they met) frequently form a system of parallels. Such a series of faces is termed a "zone." Sometimes the zones are parallel to one of the symmetrical axes. Thus, in every prism, the faces of the prism constitute a zone which encircles the axis of the prism. Faces may be in a zone although they do not actually intersect on the form.

Rationality of the parameters.

5. *The Law of the Rationality of the Parameters* of the faces of crystalline series, first indicated by Malus, is that the position of planes may be assigned by numbers bearing some simple ratio to the relative lengths of the axes of the crystal. This law was the outcome of investigations into the relationship of forms glanced at in commencing the consideration of the cubic system, and was arrived at through the study of the mode of derivation of forms.

Derivation of forms.

The derivation of forms is that process by which, from one form chosen for the purpose, and considered as the type,—the fundamental or primary form,—all the other forms of a system may be produced, according to fixed principles or general laws. In order to understand this process or method of derivation, it must be noted that the position of any plane is fixed when the position of any three points in it, not all in one straight line, is known. To determine the position, therefore, of the face of a crystal, it is only necessary to know the distance of three points in it from the centre of the crystal, which is the point in which the axes intersect each other. As the planes of all crystals are referred to their axes, the points in which the face (or its supposed extension) meets the three axes of the crystal are chosen, and the portions of the axes between these points and the centre are named parameters of the face; and the position of the face is sufficiently known when the relative length or proportion of these parameters is ascertained. When the position of one face of a simple form is thus fixed or described, all the other faces of the form are in like manner fixed in accordance with law 2, since they are all equal and similar, and have equal parameters—that is, intersect the axis in the same proportions. Hence the expression which marks or describes one face marks and describes the whole figure, with all its faces.

Parameters.

The octahedron is adopted as the primary or fundamental form of the cubic system, and distinguished by the first letter of the name, O. Its faces cut the half-axes at equal distances from the centre; so that these semiaxes, the parameters of the faces, have to each other the proportion 1 : 1 : 1. In order to derive the other forms from the octahedron, the following construction is employed.

Proportion of parameters expressed by symbols. Notation of Naumann.

Suppose a plane to be laid down perpendicular to one axis, and consequently parallel to the two other axes (or to cut them at an infinite distance, expressed by ∞, the sign of infinity); then the hexahedron or cube is produced, designated by the crystallographic sign $\infty O \infty$,—expressing the proportion of the parameters of its faces, or $\infty : 1 : \infty$. If a plane is supposed placed on each edge, parallel to one axis, and cutting the two other axes at equal distances, the resulting figure is the rhombic dodecahedron, designated by the sign ∞O, the proportion of the parameters of its faces being $\infty : 1 : 1$. The triakisoctahedron arises when, on each edge of the octahedron, planes are placed cutting the axis not belonging to that edge at a distance from the centre m, which is a rational number greater than 1. The proportion of its parameters is therefore $m : 1 : 1$, and its sign mO; the most common varieties are $\frac{3}{2}O$, $2O$, and $3O$, seen in diamond and fluorite. When, on the other hand, from a similar distance m in each two semiaxes prolonged a plane is drawn to the other semiaxis, or to each angle, an icositetrahedron is formed; the parameters of its faces have consequently the proportion $m : m : 1$, and its sign is mOm; the most common varieties are $2O2$ and $3O3$,—the former very frequent in leucite, analcime, and garnet, the latter in gold and amalgam. When, again, planes are drawn from each angle, or the end of one semiaxis of the octahedron, parallel to a second axis, and cutting the third at a distance n, greater than 1, then the tetrakishexahedron is formed; the parameter of its faces is $\infty : n : 1$; its sign is ∞On; and the most common varieties in nature are $\infty O\frac{3}{2}$, $\infty O2$, and $\infty O3$. Finally, if in each semiaxis of the octahedron two distances m and n be taken, each greater than 1, and m also greater than n, and planes be drawn from each angle to these points, so that the two planes lying over each edge cut the second semiaxis belonging to that edge at the smaller distance n, and the third axis at the greater distance m, then the hexakisoctahedron is produced; the parameters are $m : n : 1$, its sign mOn, and the most common varieties $3O\frac{3}{2}$, $4O2$, and $5O\frac{5}{3}$, seen in diamond and fluorite.

It must be observed that the numbers in the above signs refer to the parameters of the faces,—not to the axes of the crystal, which are always equal. One parameter also has always been, in the above, assumed $=1$, and then, either one only of the two other parameters, marked by the number before O, or both of them, marked by the numbers before and after O, have been changed.

In the above consideration of the mode of derivation of these forms actually found in nature, which belong to the cubic system, it will be observed (though the illustrations were limited) that the value of m and n in these indicated, by the precision of the proportions $\frac{3}{2}$, 2, or 3, a definite numerical relationship. This at once led up to the extended observations which established the law above stated of proportionality in the modification of crystals, or the rationality of the parameters, which gives a mathematical basis to the science, adding to symmetry of arrangement a numerical relation in the position of the planes.

To illustrate this in a general form (and not merely with special reference to the mode of notation or expression of Naumann, which is that adopted in the subsequent descriptions), let AOA′, BOB′, COC′ (fig. 42) be the three axes of a crystal, drawn in perspective, and cutting one another in the centre O. The semiaxes OA, OB, OC are three parameters. Now in the line OA take $Oa_2 = \frac{1}{2}OA$, and $Oa_3 = \frac{1}{3}OA$,—making as many points as may be necessary between OA, *rational fractions* of OA. Subdivide OB and OC in a similar manner. Further produce OA, OB, OC to *Ao*, *Bo*, *Co*, in each direction to an infinite distance, or to a supposed infinite distance, as expressed by the arrow-head; and suppose these extended axes to be divided in a manner similar to the subdivisions of the parameters, by rational multiples of OA, OB, and OC. *All the planes of a crystal will be parallel to one or other of the planes which pass through three of the points thus determined.*

First, in order to apprehend the relationship of faces to these axes, or to the half axes,—the parameters of the faces,—let us suppose one

plane of a crystal to be so situated as to cut the three parameters OA, OB, OC at their extremities A, B, C, which it must be remembered are points equidistant from the centre; or let it be supposed that a glass plate rests upon three intersecting wires at such points. It is evident that such a plane or plate will have a definite inclination or slope. Suppose further a second plane or plate to exist, which cuts the three semiaxes in the points a_2, b_2, c_2, which have been measured off (along with a_1, b_1, c_1) as equidistant from O. It will be evident that such a plane, though smaller, will be parallel to the first, seeing that, like it, it cuts the three parameters at equal distances from O.

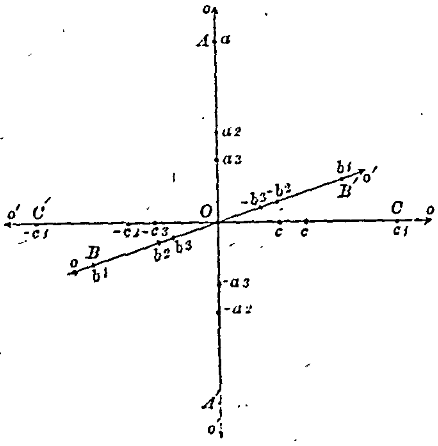


Fig. 12.

A little consideration will show that, whatever the absolute distances from the centre may be, so long as the supporting subdivisions are equal, no new slope of the glass plates or planes is possible; planes so situated must be parallel and similar. Any sign which may be adopted to express the slope of one of such planes must be applicable to all. A plane, however, cutting the points a_1, b_1, c_2 will have quite a different slope.

Let us now suppose a plane to cut a different set of the semiaxes, namely, OA′, OB′, OC′, in the points $-a_1$, $-b_1$, $-c_1$. Such a plane would be parallel to one cutting the points $-a_2$, $-b_2$, $-c_2$, and also to the set of planes first described, but on the opposite side of the centre of the crystal. If again, however, we had a plane cutting the semiaxes OA′ and OB′ in $-a_1$, $-b_1$, but the semiaxis OC′ in the point $-c_2$, it is clear that the slope of this plane would be quite different from that of the planes just described, but it would be parallel to the plane cutting the points a_1, b_1, c_2. This slope, like the other, evidently depends, not on the absolute lengths of the portions of OA′, OB′, OC′ cut off, but upon their proportions or ratios; and such is the case with all the planes which are referred to the same axes.

As there are three axes, and each or all of them may be cut at any points and at any ratios, it is evident that the number of planes which is possible is infinite; and it must be also evident that the inclinations of all are fixed or determinate if we know the ratios. While, however, the possible number of planes is infinite, the actual number occurring among minerals is either small or moderate, in virtue of the fact that the ratios of subdivision of the axes are always simple, and not numerous.

Other modes of notation. Naumann's symbols for the notation or individualizing of planes have been glanced at. A simpler method is that of employing as indices the denominators (if simple fractions) of the fractional parts of the axis cut. Thus 111 is used for any plane parallel to that cutting the axes in a_1, b_1, c_1; 122 for those parallel to a_1, b_2, c_2; 313 for a_3, b_1, c_3; and so on.

When any of the points referred to have negative signs, the corresponding indices have negative signs placed over them. Thus $\bar{1}22$ is the index for a plane parallel to $a'_1 b_2 c_2$. $\bar{1}0\bar{3}$ is the index of the plane a'_1, $b\infty$, c'_3. ∞ here indicates infinity; that is, the plane never would cut the axis B however far it were extended; in other words, it is parallel to it. The necessity for elongating the axes is brought about by the occurrence of highly acuminating planes, which in many cases would not meet the axes at all unless these were prolonged.

If the axes are unequal, as in the trimetric forms, then the ratio is of the same character, except that the relative lengths of the axes come into consideration; but here, as in the regular system, irrational values cannot occur, and in even the most complex crystals they seldom exceed seven, either as aliquot parts or multiples.

It will thus be seen that in crystals there is no haphazard scattering of faces, but a complete subserviency to law, a law which may be said to be the linear equivalent to the law of multiple proportions by weight, and Gay Lussac's law of multiple proportions in combination by volume.

In abbreviation of all the systematic modes of notation, letters of the Latin and Greek alphabets are frequently employed in a more or less arbitrary manner, and with advantage in the case of highly complex forms.

Symmetry of combination. 6. *The Law of Symmetry of Crystalline Combination* is the consequence of the law of symmetry and the law of the rationality of the parameters, and has been partially stated in enunciating these laws. It is thus expressed:—(1) a substance can only crystallize in forms, whether simple or compound, which have the same relative symmetry, that is, belong to the same crystalline system, and the parameters of the faces of which bear a simple relation to each other, that is, belong to the same axis; (2) a form cannot be modified by faces belonging to a different system, or a different series.

Apparent exceptions. Certain exceptions to the first part of this law occur. The element carbon occurs as the diamond, which is cubic, and as graphite, which is hexagonal. Sulphur occurs near volcanoes in needle crystals belonging to the oblique prismatic system, and also in caves (deposited apparently from solution) in crystals belonging to the right prismatic system. Titanic acid is tetragonal in rutile, and right prismatic in brookite. Carbonate of lime is hexagonal in calcite, and prismatic in aragonite. These are probably only apparent exceptions. The elementary substances which go to form them occur in different allotropic states, with different amounts of specific heat; and it is probable that in these different states they go to form the above modifications, which are therefore, in every respect, except in their chemical composition, different mineral bodies. The physical differences between diamond and graphite may suffice as an illustration. The diamond is transparent, colourless, brittle, and extremely hard; graphite is opaque, black, tough, and so soft as to be utilized as a lubricant.

Spheres of Projection.—The foregoing scheme for the development of the relation which subsists between faces of crystals and their axes affords but slight aid in displaying the position of the faces, or their mutual relationships. The delineation even of a considerable series of crystal forms does not indeed go far in effecting this,—on account, first, of very unequal development in the size of the faces of crystals, and, secondly, on account of the *habit* of development of these faces not only differing largely, but being special to certain localities,—as in the entire absence of some faces, and in the preponderance of others.

Spheres of projection. Maps of the whole domain occupied by the forms of each mineral have been happily projected for such display. The projection is laid down as on a globe, in accordance with stereographic projection, and admitting of calculation according to the laws of spherical trigonometry. These globe maps are called "spheres of projection." The centre O is the common centre of the crystal and of the sphere in which the axes intersect. The three axes will of course meet the circumference of the sphere in six points, called the "poles of the axes." From the centre radii are supposed to be drawn, meeting each plane perpendicularly. It is evident that such radii will have fixed inclinations to each other. They are called "normals" to the planes, and the points in which when produced they meet the circumference of the sphere of projection are called the "poles" of the corresponding faces. A face and its pole thus call for only one symbol. The angle included by any two normals is the supplement of that included by the two corresponding faces.

It is thus easy to determine the angles of any two normals when that of the corresponding faces is known, or *vice versa*. Thus, if the angle between two faces is 125°, that of the normals will be 55°. The spheres of projection are specially adapted to enable us to avail ourselves of the aid to calculation afforded by the forenoted fact that sets of faces lie parallel to each other, forming zones; for, when

Zones. projected on such a sphere, the normals of the parallel faces will all lie in one plane; and the poles, all cutting its surface in the direction of one line, may be connected, and so form a great circle on the sphere. This is called the "zone circle." A line drawn through the centre of the

zone plane, cutting it at right angles, is the "zone axis"; it is parallel to all the faces, and intersections of the faces (if they are extended enough to intersect), of the zone. A face may be common to two or more zones; its normals will then coincide with the intersections of the several zone planes.

In the absence of actual spheres upon which to detail the facts which go to form the "sphere of projection" of each substance, the hemisphere is represented on a plane surface. This has of necessity the disadvantage, except as regards the circumferential zone, of introducing spherical distance-distortion—foreshortening of all parts lying near the circumference; but the eye soon gets accustomed to this. Fig. 43 presents the principal zones of the cubic system, and

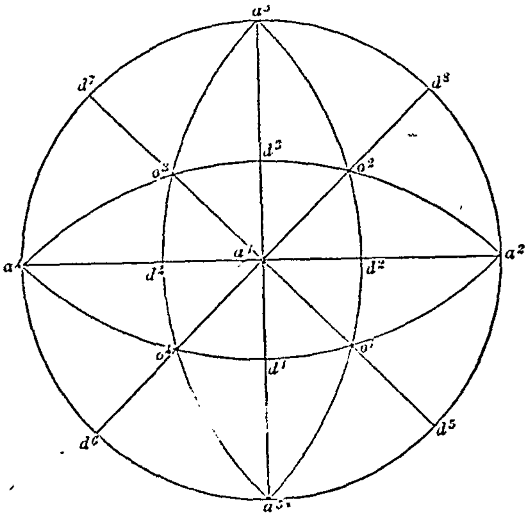


Fig. 43.

shows the position of the poles of the faces of the cube, the octahedron, and the rhombic dodecahedron. o_1, o_2, o_3, &c., are the poles of the octahedral faces; a_1, a_2, a_3, &c., those of the faces of the cube; and d_1, d_2, d_3, &c., those of the rhombic dodecahedron. It will be observed that the faces of the cube fall into the zone circles of the octahedron and dodecahedron, while those of the octahedron fall into those

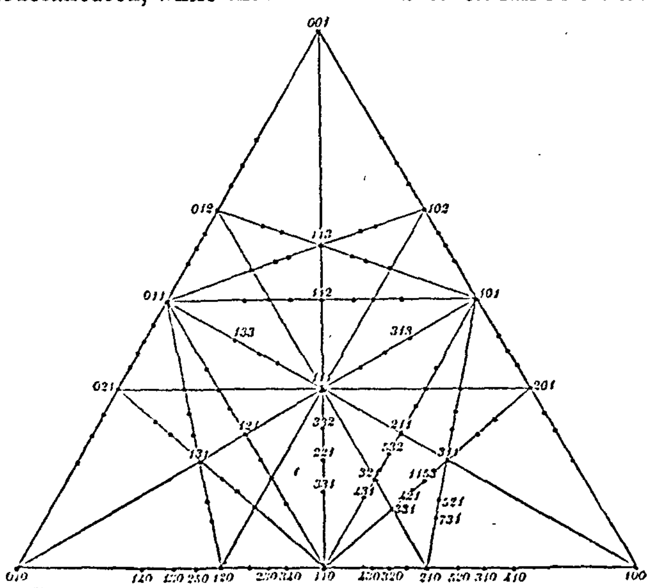


FIG 44.—Principal Poles of Cubic System in Octant of Sphere.

of the rhombic dodecahedron. Considering this as a delineation of a globe, these zone circles come to represent latitude and longitude; and, as almost all the faces in this system fall into some zone circle, it is clear that the latitude and longitude of all normals may be readily laid down, and their relations at once determined by spherical trigonometry. Fig. 44 shows the arrangement of the poles of all the forms belonging to the cubic system noticed above, or referred to in the present article,—delineated on an octant of the sphere of projection. It displays the perfect regularity of the system.

Hemihedral and Tetartohedral Forms.—The exception to the second law (that of symmetry), which was formulated by Weiss, was to the effect that one-half or even one-fourth only of the faces which go to form a holohedral crystal may be present. When but one-half of the faces present themselves, the form is termed hemihedral; when only one-fourth, it is tetartohedral. These restrained developments have now to be considered. In hemihedral forms the development is restrained, but symmetry is not deranged; half the similar parts are still alike, though unlike the other half.

There are two classes of hemihedral forms:—

I. Those forms in which half the similar angles or edges are modified independently of the other half ("hemi-holohedral"), producing—

1. In the monometric and dimetric systems "tetrahedral" and "sphenoidal" forms, by the independent replacement of the alternate angles; their opposite faces are not parallel, and they are hence called "inclined" hemihedrons; as in chalcopyrite, boracite.[1] The replacement in the dimetric system of two opposite basal edges at one base and the other two at the opposite base is of the same kind; as in edingtonite.

2. In the trimetric system "monoclinic" forms, by the replacement of half the similar parts of one base and the diagonally opposite of the other, unlike the other half; as in datholite, humite.

3. In the trimetric and hexagonal systems "hemimorphic" forms, by independent replacements at the opposite extremities of the crystal; as in topaz, calamine, tourmaline.

4. In the rhombohedral system, by the replacements of the alternate basal edges or angles of the rhombohedron, forms usually called "tetartohedral" or quarter forms, on the ground that mathematically the rhombohedron is a hemihedral form derived from the hexagonal prism, which is the type of the hexagonal system. Rock crystal is usually developed according to this law.

II. Those forms in which all the similar angles or edges are modified, but by half the full or normal number of planes ("holo-hemihedral"), producing—

1. In the monometric system "pyritohedral" forms, by a replacement of the edges or angles; as in pyrites. Such forms have opposite faces parallel, and are often called parallel hemihedrons.

2. In the dimetric system "pyramidal" and "scalenoidal" forms, by a replacement of the eight solid angles of the primary prism, according to two methods.

3. In the hexagonal system "pyramoidal" and "gyroidal" forms, by a replacement of the solid angles of the hexagonal prism, or of the six lateral angles of the rhombohedron, according to two methods, as in quartz and apatite.

The above illustrations show that hemihedrism is not only divided into two classes, but is of various kinds, and these have been systematized as follows:—"holomorphic," in which the occurring planes pertain equally to the upper and lower (or opposite) ranges of sectants, as in ordinary hemihedrons; and (2) "hemimorphic," in which each set of planes pertains to either the upper or the lower range, but not to both. As to the relative position of the sectants which contain the planes, the forms may be vertically direct, as in baryte; vertically alternate, as in the tetrahedron, the rhombohedron, and the plagihedral faces of quartz; and vertically oblique, as in many forms of chondrodite.

In hemimorphic forms symmetry is deranged; the crystals are bounded at the opposite ends of their main axes by faces belonging to distinct forms or modifications,—always, however, of the same system; hence only the upper or the under half of each crystal can be regarded as complete, as regards the form there seen; and so for each end it is half formed.

Fig. 45 represents a crystal of tourmaline, which is bounded on the upper end by the planes of the rhombohedrons R (P) and -2R (o), and on the lower end by the basal pinacoid (k'). In fig. 46 of smithsonite the upper extremity shows the base k, two brachydomes o and p, and two macrodomes m and l;

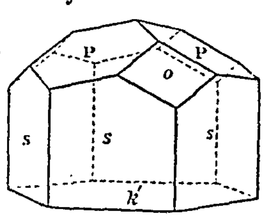


Fig. 45.

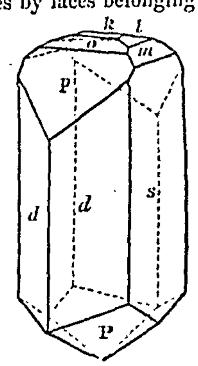


Fig. 46.

[1] As the parts of either half are alternate, there still results a symmetrical solid. As either one or other half may be the one thus modified, there may result two such symmetric solids, which stand in an inverse position to one another. When the modifications affect the upper right-hand solid angle, the resulting form is called +; when the upper left hand angle it is −.

whilst on the lower end it is bounded by the faces P of the primary alone.

It has been found that all hemimorphic crystals become electrically polar when heated, that is, exhibit opposite kinds of electricity at opposite ends of the crystal. The subject will be more fully considered under the electricity of minerals.

emi- edral rms. The hemihedral forms of the cubic system are the following :—

1. The *tetrahedron (fig. 47), hemihedral of the octahedron, is* bounded by *four equilateral triangles.* It has six equal edges with *faces meeting at* 70° 32′, and four trigonal angles. The principal axes join the middle points of each two opposite edges. Examples: fahlore, boracite, and helvine.

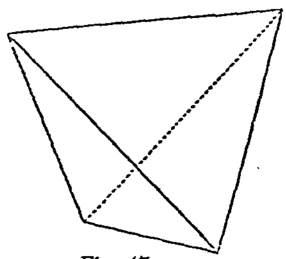


Fig. 47.

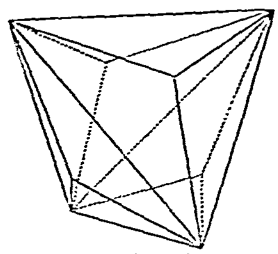


Fig. 48.

2. The trigonal dodecahedrons (fig. 48), hemihedral of the icositetrahedron, are bounded by twelve isosceles triangles, and vary in general form from the tetrahedron to the cube. There are six longer edges corresponding to those of the inscribed tetrahedron, and twelve shorter, placed three and three over each of its faces, and four hexagonal and four trigonal angles. Example : tetrahedrite.

3. The deltoid dodecahedrons (fig. 49), hemihedral of the triakisoctahedron, are bounded by twelve deltoids, and vary in general form from the tetrahedron on the one hand to the rhombic dodecahedron on the other. They have twelve longer edges lying in pairs over the edges of the inscribed tetrahedron, and twelve shorter edges, three and three over each of its faces. There are six tetragonal (rhombic), four acute trigonal, and four obtuse trigonal angles. The principal axes join, two and two, opposite rhombic angles. Example : tetrahedrite.

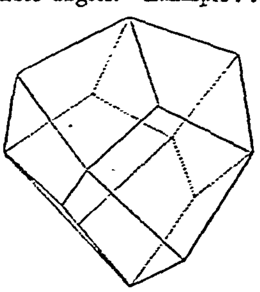


Fig. 49.

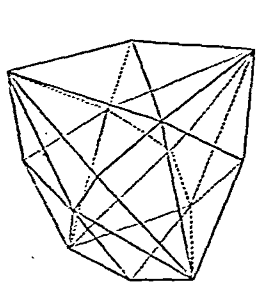


Fig. 50.

4. The hexakistetrahedrons (fig. 50), hemihedral of the hexakisoctahedron, are bounded by twenty-four scalene triangles, and most commonly have their faces grouped in four systems of six each. The edges are twelve shorter and twelve longer, lying in groups of three over each face of the inscribed tetrahedron, and twelve intermediate in pairs over its edges. The angles are six rhombic, joined in pairs by the principal axes, and four acuter and four obtuser hexagonal angles. Example : diamond.

In these forms, often named "tetrahedral," the faces are oblique to each other. Their derivation and signs are as follows. The tetrahedron arises when four alternate faces of the octahedron, two opposite above and two intermediate below, are enlarged so as to obliterate the other four; and its sign is hence $\frac{O}{2}$. But, as either four faces may be thus enlarged or obliterated, two tetrahedrons can be formed, similar in all respects except in position, and together making up the octahedron. These are distinguished by the signs + and −, added to the above symbol, but only the latter in general expressed, thus $-\frac{O}{2}$. In all hemihedric systems two forms similarly related occur, which may thus be named complementary forms. The trigonal dodecahedron is derived from the icositetrahedron by the expansion of the alternate trigonal groups of faces. Its sign is $\frac{mOm}{2}$, the most common variety being $\frac{2O2}{2}$. The deltoid dodecahedron is in like manner the result of the increase of the alternate trigonal groups of faces of the triakisoctahedron, and its sign is $\frac{mO}{2}$. Lastly, the hexakistetrahedron arises in the development of alternate hexagonal groups of faces in the hexakisoctahedron, and its sign is $\frac{mOn}{2}$.

Two semitesseral forms with parallel faces occur. (1) The pentagonal dodecahedrons (fig. 51), bounded by twelve *symmetrical* pentagons, vary in general aspect between the cube and the rhombic dodecahedron. They have six regular (and in general longer) edges, lying over the faces of the inscribed cube, and twenty-

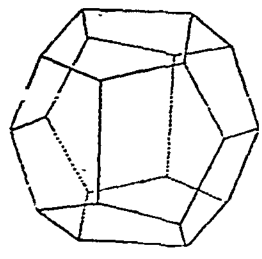


Fig. 51.

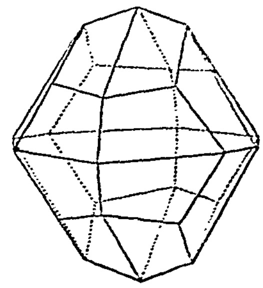


Fig. 52.

four, generally shorter (seldom longer), edges, usually lying in pairs over its edges. The solid angles are eight of three equal interfacial angles, and twelve of three interfacial angles, of which only two are equal. Each principal axis unites two opposite regular edges. This form is derived from the tetrakishexahedron, and its sign is $\frac{\infty On}{2}$. It is found frequently in iron pyrites and cobaltine.

(2) The dyakisdodecahedron (fig. 52), bounded by twenty-four trapezoids with two sides equal, has twelve short, twelve long, and twenty-four intermediate edges. The angles are six equiangular rhombic, united in pairs by the principal axes, eight trigonal, and twenty-four irregular tetragonal angles. It is derived from the hexakisoctahedron, and its sign is $\left[\frac{mOn}{2}\right]$, the brackets being used to distinguish it from the hexakistetrahedron, also derived *from the same primary form. It occurs in iron pyrites and* cobaltine. The two other semitesseral forms, the pentagonal

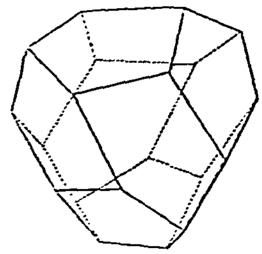


Fig. 53.

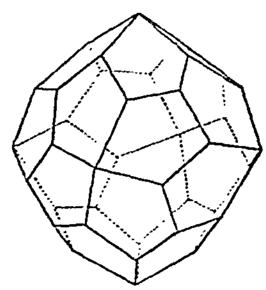


Fig. 54.

dodecahedron (fig. 53), and the pentagonal icositetrahedron (fig. 54), both bounded by *irregular* pentagons, have not yet been observed in nature.

Combinations.—The above-mentioned forms of the tesseral system (and this is true also of the five other systems of crystallization) not only occur singly, but often two, three, or more occur united in the same crystal, forming what are named combinations. Combinations.

In this case it is evident that no one of the individual forms can be complete, because the faces of one form must interfere with, by diminishing, the faces of other forms. A combination therefore implies that the faces of one form shall appear symmetrically disposed between the faces of other forms, and consequently take the place of certain of their edges and angles. These edges and angles are thus, as it were, cut off, and a greater number of new ones produced in their place, which properly belong neither to the one form nor the other, but are angles of combination. These new faces are hence termed modifications, and the original or primary or simple form is said to be modified. Usually one form predominates more than the others, or has more influence on the general aspect of the crystal, and hence is distinguished as the predominant form, the others being considered subordinate.

The sign of the combination consists of those of its constituent forms, written in the order of their influence or importance in the combination, with a point between each pair.

It will be readily seen that such combinations may be exceedingly numerous, or rather infinite; and only a few of the more common

zone plane, cutting it at right angles, is the "zone axis"; it is parallel to all the faces, and intersections of the faces (if they are extended enough to intersect), of the zone. A face may be common to two or more zones; its normals will then coincide with the intersections of the several zone planes.

In the absence of actual spheres upon which to detail the facts which go to form the "sphere of projection" of each substance, the hemisphere is represented on a plane surface. This has of necessity the disadvantage, except as regards the circumferential zone, of introducing spherical distance-distortion—foreshortening of all parts lying near the circumference; but the eye soon gets accustomed to this. Fig. 43 presents the principal zones of the cubic system, and

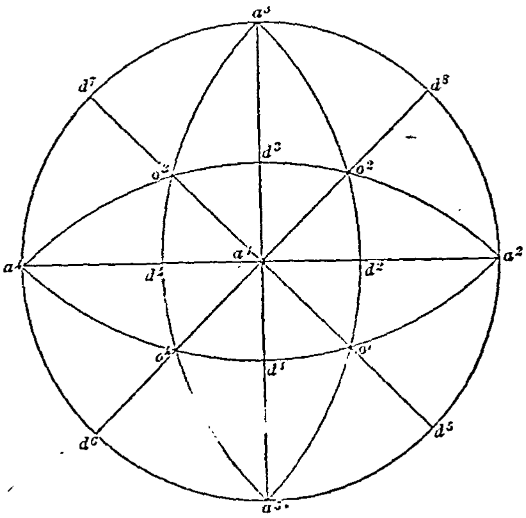


Fig. 43.

shows the position of the poles of the faces of the cube, the octahedron, and the rhombic dodecahedron. o_1, o_2, o_3, &c., are the poles of the octahedral faces; a_1, a_2, a_3, &c., those of the faces of the cube; and d_1, d_2, d_3, &c., those of the rhombic dodecahedron. It will be observed that the faces of the cube fall into the zone circles of the octahedron and dodecahedron, while those of the octahedron fall into those

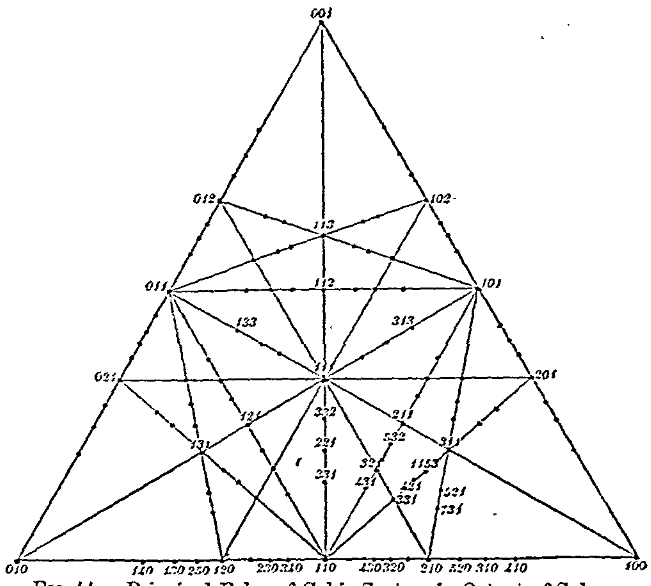


Fig 44.—Principal Poles of Cubic System in Octant of Sphere.

of the rhombic dodecahedron. Considering this as a delineation of a globe, these zone circles come to represent latitude and longitude; and, as almost all the faces in this system fall into some zone circle, it is clear that the latitude and longitude of all normals may be readily laid down, and their relations at once determined by spherical trigonometry. Fig. 44 shows the arrangement of the poles of all the forms belonging to the cubic system noticed above, or referred to in the present article,—delineated on an octant of the sphere of projection. It displays the perfect regularity of the system.

Hemihedral and Tetartohedral Forms.—The exception to the second law (that of symmetry), which was formulated by Weiss, was to the effect that one-half or even one-fourth only of the faces which go to form a holohedral crystal may be present. When but one-half of the faces present themselves, the form is termed hemihedral; when only one-fourth, it is tetartohedral. These restrained developments have now to be considered. In hemihedral forms the development is restrained, but symmetry is not deranged; half the similar parts are still alike, though unlike the other half.

There are two classes of hemihedral forms:—

I. Those forms in which half the similar angles or edges are modified independently of the other half ("hemi-holohedral"), producing—

1. In the monometric and dimetric systems "tetrahedral" and "sphenoidal" forms, by the independent replacement of the alternate angles; their opposite faces are not parallel, and they are hence called "inclined" hemihedrons; as in chalcopyrite, boracite.[1] The replacement in the dimetric system of two opposite basal edges at one base and the other two at the opposite base is of the same kind; as in edingtonite.

2. In the trimetric system "monoclinic" forms, by the replacement of half the similar parts of one base and the diagonally opposite of the other, unlike the other half; as in datholite, humite.

3. In the trimetric and hexagonal systems "hemimorphic" forms, by independent replacements at the opposite extremities of the crystal; as in topaz, calamine, tourmaline.

4. In the rhombohedral system, by the replacements of the alternate basal edges or angles of the rhombohedron, forms usually called "tetartohedral" or quarter forms, on the ground that mathematically the rhombohedron is a hemihedral form derived from the hexagonal prism, which is the type of the hexagonal system. Rock crystal is usually developed according to this law.

II. Those forms in which all the similar angles or edges are modified, but by half the full or normal number of planes ("holo-hemihedral"), producing—

1. In the monometric system "pyritohedral" forms, by a replacement of the edges or angles; as in pyrites. Such forms have opposite faces parallel, and are often called parallel hemihedrons.

2. In the dimetric system "pyramidal" and "scalenoidal" forms, by a replacement of the eight solid angles of the primary prism, according to two methods.

3. In the hexagonal system "pyramoidal" and "gyroidal" forms, by a replacement of the solid angles of the hexagonal prism, or of the six lateral angles of the rhombohedron, according to two methods, as in quartz and apatite.

The above illustrations show that hemihedrism is not only divided into two classes, but is of various kinds, and these have been systematized as follows:—"holomorphic," in which the occurring planes pertain equally to the upper and lower (or opposite) ranges of sectants, as in ordinary hemihedrons; and (2) "hemimorphic," in which each set of planes pertains to either the upper or the lower range, but not to both. As to the relative position of the sectants which contain the planes, the forms may be vertically direct, as in baryte; vertically alternate, as in the tetrahedron, the rhombohedron, and the plagihedral faces of quartz; and vertically oblique, as in many forms of chondrodite.

Hemimorphic forms.

In hemimorphic forms symmetry is deranged; the crystals are bounded at the opposite ends of their main axes by faces belonging to distinct forms or modifications,—always, however, of the same system; hence only the upper or the under half of each crystal can be regarded as complete, as regards the form there seen; and so for each end it is half formed.

Fig. 45 represents a crystal of tourmaline, which is bounded on the upper end by the planes of the rhombohedrons R (P) and -2R (o), and on the lower end by the basal pinacoid (k'). In fig. 46 of smithsonite the upper extremity shows the base k, two brachydomes o and p, and two macrodomes m and l;

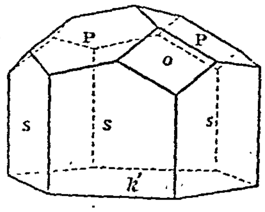


Fig. 45.

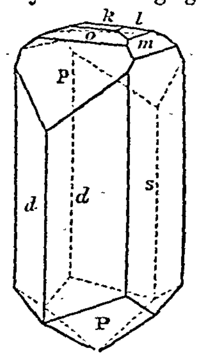


Fig. 46.

[1] As the parts of either half are alternate, there still results a symmetrical solid. As either one or other half may be the one thus modified, there may result two such symmetric solids, which stand in an inverse position to one another. When the modifications affect the upper right-hand solid angle, the resulting form is called +; when the upper left hand angle it is −.

whilst on the lower end it is bounded by the faces P of the primary alone.

It has been found that all hemimorphic crystals become electrically polar when heated, that is, exhibit opposite kinds of electricity at opposite ends of the crystal. The subject will be more fully considered under the electricity of minerals.

Hemihedral forms.

The hemihedral forms of the cubic system are the following:—

1. The tetrahedron (fig. 47), hemihedral of the octahedron, is bounded by four equilateral triangles. It has six equal edges with faces meeting at 70° 32′, and four trigonal angles. The principal axes join the middle points of each two opposite edges. Examples: fahlore, boracite, and helvine.

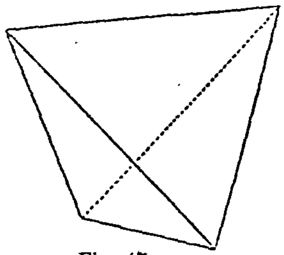


Fig. 47.

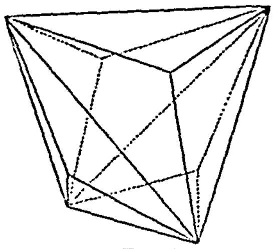


Fig. 48.

2. The trigonal dodecahedrons (fig. 48), hemihedral of the icositetrahedron, are bounded by twelve isosceles triangles, and vary in general form from the tetrahedron to the cube. There are six longer edges corresponding to those of the inscribed tetrahedron, and twelve shorter, placed three and three over each of its faces, and four hexagonal and four trigonal angles. Example: tetrahedrite.

3. The deltoid dodecahedrons (fig. 49), hemihedral of the triakisoctahedron, are bounded by twelve deltoids, and vary in general form from the tetrahedron on the one hand to the rhombic dodecahedron on the other. They have twelve longer edges lying in pairs over the edges of the inscribed tetrahedron, and twelve shorter edges, three and three over each of its faces. There are six tetragonal (rhombic), four acute trigonal, and four obtuse trigonal angles. The principal axes join, two and two, opposite rhombic angles. Example: tetrahedrite.

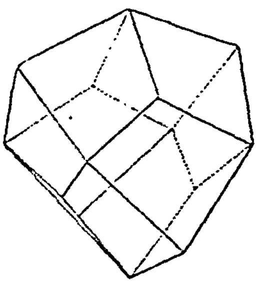


Fig. 49.

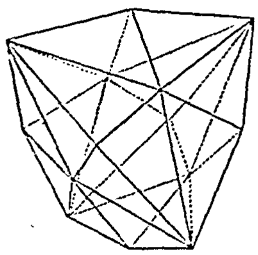


Fig. 50.

4. The hexakistetrahedrons (fig. 50), hemihedral of the hexakisoctahedron, are bounded by twenty-four scalene triangles, and most commonly have their faces grouped in four systems of six each. The edges are twelve shorter and twelve longer, lying in groups of three over each face of the inscribed tetrahedron, and twelve intermediate in pairs over its edges. The angles are six rhombic, joined in pairs by the principal axes, and four acuter and four obtuser hexagonal angles. Example: diamond.

In these forms, often named "tetrahedral," the faces are oblique to each other. Their derivation and signs are as follows. The tetrahedron arises when four alternate faces of the octahedron, two opposite above and two intermediate below, are enlarged so as to obliterate the other four; and its sign is hence $\frac{O}{2}$. But, as either four faces may be thus enlarged or obliterated, two tetrahedrons can be formed, similar in all respects except in position, and together making up the octahedron. These are distinguished by the signs + and −, added to the above symbol, but only the latter in general expressed, thus $-\frac{O}{2}$. In all hemihedric systems two forms similarly related occur, which may thus be named complementary forms. The trigonal dodecahedron is derived from the icositetrahedron by the expansion of the alternate trigonal groups of faces. Its sign is $\frac{mOm}{2}$, the most common variety being $\frac{2O2}{2}$. The deltoid dodecahedron is in like manner the result of the increase of the alternate trigonal groups of faces of the triakisoctahedron, and its sign is $\frac{mO}{2}$. Lastly, the hexakistetrahedron arises in the development of alternate hexagonal groups of faces in the hexakisoctahedron, and its sign is $\frac{mOn}{2}$.

Two semitesseral forms with parallel faces occur. (1) The pentagonal dodecahedrons (fig. 51), bounded by twelve *symmetrical* pentagons, vary in general aspect between the cube and the rhombic dodecahedron. They have six regular (and in general longer) edges, lying over the faces of the inscribed cube, and twenty-

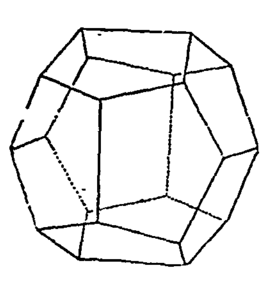


Fig. 51.

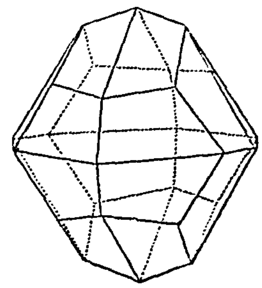


Fig. 52.

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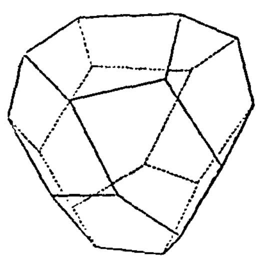

Fig. 53.

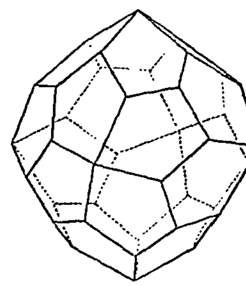

Fig. 54.

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Combinations.

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In this case it is evident that no one of the individual forms can be complete, because the faces of one form must interfere with, by diminishing, the faces of other forms. A combination therefore implies that the faces of one form shall appear symmetrically disposed between the faces of other forms, and consequently take the place of certain of their edges and angles. These edges and angles are thus, as it were, cut off, and a greater number of new ones produced in their place, which properly belong neither to the one form nor the other, but are angles of combination. These new faces are hence termed modifications, and the original or primary or simple form is said to be modified. Usually one form predominates more than the others, or has more influence on the general aspect of the crystal, and hence is distinguished as the predominant form, the others being considered subordinate.

The sign of the combination consists of those of its constituent forms, written in the order of their influence or importance in the combination, with a point between each pair.

It will be readily seen that such combinations may be exceedingly numerous, or rather infinite; and only a few of the more common

can be noticed. Many others more complicated will occur in the descriptive part of this article. Among holohedral combinations, the cube, octahedron, and rhombic dodecahedron are the predominant forms. In fig. 27 the cube has its angles replaced by the faces of the octahedron, which truncate the angles, and the sign of this combination is $\infty O \infty$, O. In fig. 28 this process may be regarded as having proceeded still farther, so that the faces of the octahedron nearly equal those of the cube, while in fig. 29 they now predominate; the sign, still of the same two elements, but in reverse order, is O, $\infty O \infty$. It will thus be seen that, through an increase in the amount of the abstraction of the faces of the cube, the figure gradually passes over into that of the octahedron. This may occur in all cases, and is termed the passage of the cube into the octahedron (or *vice versa*), or a "transition by decrement."

In fig. 31 the cube has its edges replaced by the faces of the rhombic dodecahedron, which truncate the edges, the sign being $\infty O \infty$, ∞O; while in fig. 32 there is the same combination, but with the faces of the cube subordinate, and hence the sign is ∞O, $\infty O \infty$. The former figure, it will be seen, has more the general aspect of the cube, the latter of the dodecahedron. Here the solid angles of the latter are truncated by the faces of the cube, and we have the passage of the cube into the dodecahedron by decrement. The same transition, through truncation or decrement, could be shown in all cases of combinations, and in both directions, the last stage of the passage into one or other form always consisting of the replacement of its solid or interfacial angles by faces of the departing figure, more or less minute. A few illustrations of this may be given, in the three most important forms.

The relationship of the tetrakishexahedron to the cube has above been stated to be, that its faces form six low quadrilateral pyramids, which rest upon or spring from the edges of the cube. (From this the form derives its trivial name of four-faced cube.) Hence these faces bevel the edges of the cube. The first stage of such bevelling (or the last stage of the truncation of the tetrakishexahedron by the faces of the cube—whichever way it may be regarded) is seen in fig. 55. As the cubic face is here dominant, the sign is $\infty O \infty$, $\infty O3$. Fig. 56 shows a somewhat similar stage

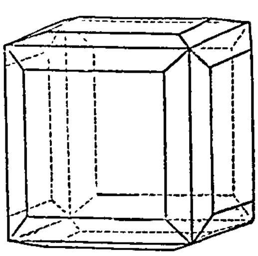


Fig. 55.

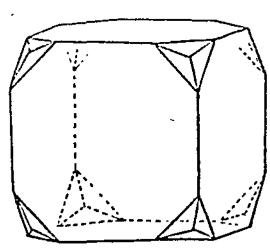


Fig. 56.

in the modification produced through the combination of the icositetrahedron with the cube. The trilateral pyramid which this form places upon the faces of the cube rests upon its solid angles, instead of, as in the last case, upon its edges; hence it is these solid angles which, in the process of decrement, it replaces by faces which form a low three-sided pyramid. The triakisoctahedron,

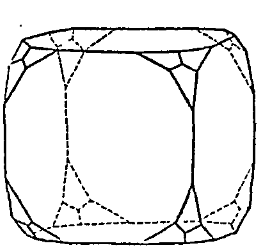


Fig. 57.

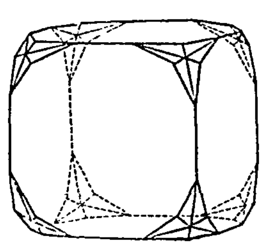


Fig. 58.

again, modifies the solid angles of the cube, as shown in fig. 57, by a low three-sided pyramid, positioned at right angles to that considered in the last combination. As the hexakisoctahedron is merely the two-faced form of that last considered, the pyramid which modifies the solid angles is, in its combination with the cube, six-sided, as in fig. 58.

As the faces of the rhombic dodecahedron truncate the edges of the octahedron, fig. 34 represents the first stage of such truncation or combination; while fig. 35 may be taken as representing the last, the faces of the octahedron being there nearly totally removed.

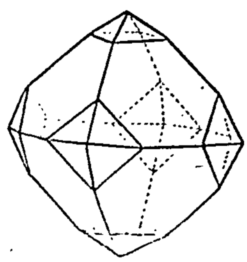


Fig. 59.

Fig. 59 shows the first stage of the passage of the octahedron into the icositetrahedron, in the truncation of the solid angles of the former form by a four-sided pyramid formed by the (6 × 4) faces of the latter. The faces of the octahedron truncate the three-faced solid angles of the rhombic dodecahedron. Fig. 35 shows the first stage of this truncation, while fig. 34 shows an advanced amount. The faces of the icosi-

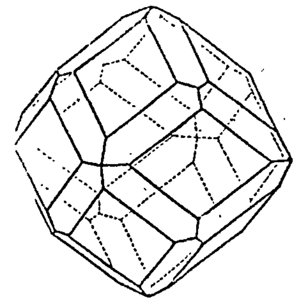


Fig. 60.

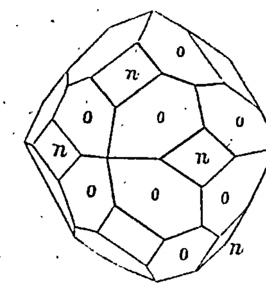


Fig. 61.

tetrahedron truncate the edges of the rhombic dodecahedron, as in fig. 60; while those of the latter truncate the unequal-angled tetragonal (or rhombic) angles of the former (fig. 61). The faces of the hexakisoctahedron bevel the edges of the rhombic dodecahedron.

While such transitions may appear indefinite, yet certain minerals have either in themselves a habit, or have at certain localities a habit, of crystallizing so markedly *in a certain stage* of these transitions as to be absolutely capable of recognition thereby.

Combinations of hemihedral or, as they have been called, semitesseral forms are of three classes:—those with holohedral forms, those in which the faces fall obliquely on one another, and those with parallel faces. Fig. 62 shows the combination of a right- Comb tions hemi- hedra forms

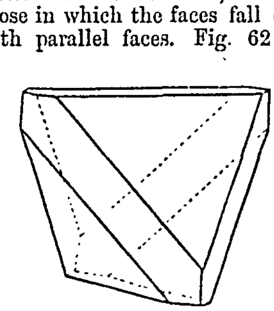


Fig. 62.

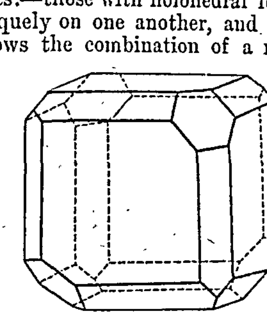


Fig. 63.

handed tetrahedron with the cube, which truncates its edges, the tetrahedron here being dominant. Fig. 63, again, shows a combination of the cubo-dodecahedron with a right-handed tetrahedron, the first or holohedral form being in this case markedly dominant.

Fig. 64 is an illustration of the second class, combinations of

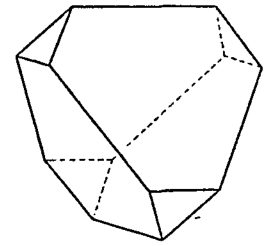


Fig. 64.

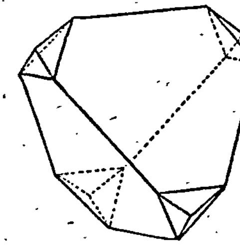


Fig. 65.

oblique-faced semitesseral forms with each other. In it a right-handed tetrahedron has its solid angles truncated by the faces of one which is left-handed; and so its sign is $\frac{O}{2}, -\frac{O}{2}$. Fig. 65 shows a combination of a right-handed tetrahedron with a left-

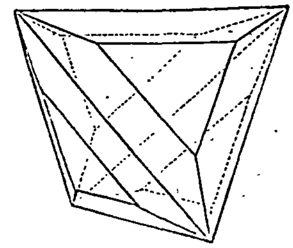


Fig. 66.

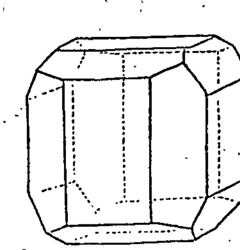


Fig. 67.

handed three-faced tetrahedron. Fig. 66 shows a combination of a right-handed hemihedron of the icositetrahedron with a right-handed tetrahedron.

Parallel-faced hemihedrons generally form combinations with holohedral forms; and the amount of relative dominance is of all degrees. Fig. 67 shows a combination, in equal amount, of the cube

with a vertical-faced pentagonal dodecahedron; while fig. 68 shows an increase in the amount of truncation effected by the latter. Fig. 69 shows the combination of the cube with the dyakidodecahedron,

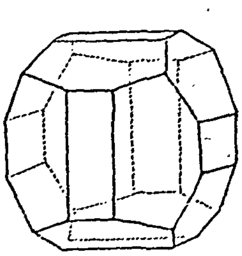


Fig. 68.

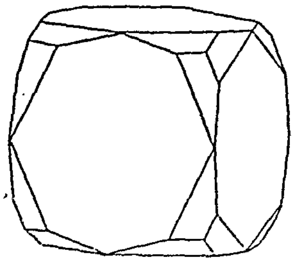


Fig. 69.

the former being dominant. In fig. 70 an octahedron, in dominance, is combined with the vertical-faced pentagonal dodecahedron; in

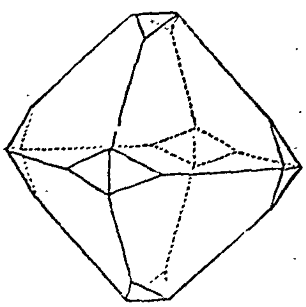


Fig. 70.

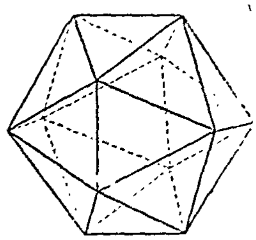


Fig. 71.

fig. 71 the faces of these forms are of nearly equal size, while in fig. 72 the octahedral faces are nearly removed. The solid angles of

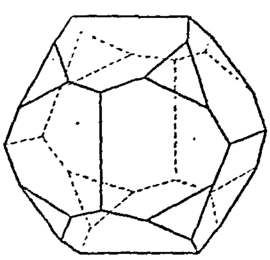


Fig. 72.

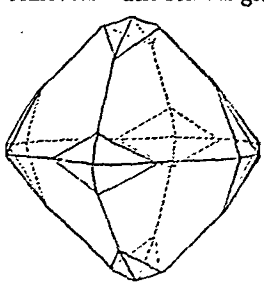


Fig. 73.

the octahedron are modified in fig. 73 by the faces of the dyakisdodecahedron. In fig. 68 a vertical-faced pentagonal dodeca-

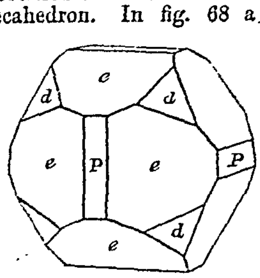


Fig. 74.

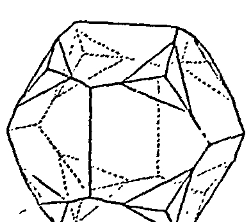


Fig. 75.

hedron is the prevailing form in combination with the cube; while in fig. 74 the faces of the octahedron are superadded. In fig. 75 its octahedral angles are modified by the faces of the icositetrahedron,

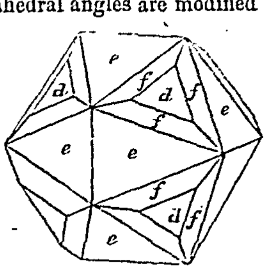


Fig. 76.

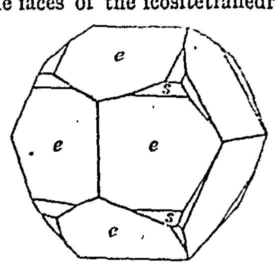


Fig. 77.

and in fig. 76 by those of the octahedron in addition. In fig. 77 they are modified by the faces of the dyakisdodecahedron.

In each of the five systems which follow there is this difference from the cubic system that one axis is always unequal to (longer or shorter than) the others. This is placed erect, and named the chief axis; its ends are poles, and the edges connected with them polar edges. The other axes are named subordinate or lateral axes, and the plane that passes through them is the base. A plane through the chief and a lateral axis is a normal chief section. In these systems also occur the three forms of "pyramids," "prisms," and "pinacoids." (1) The pyramids have their faces triangles. Pyramids in crystallography are each composed of two geometric pyramids placed base to base, and named "closed forms," as the crystals are shut in by definite faces on every side. (2) The prisms are bounded by plane faces parallel to one axis. They are thus of unlimited extent in the direction of that axis, and therefore named "open forms," but in solid crystals are shut in by faces of other forms. (3) The pinacoids, or tables, have two faces intersecting one axis and parallel to the others, and thus are also open forms, or unlimited in the direction of these axes. Forms (2) and (3), when conjoined, mutually shut in each other, or produce closed forms. Dimetric and trimetric forms.

II. *Pyramidal or Tetragonal System.*—This system has three axes at right angles, two of them equal, and the chief axis longer or shorter. The name tetragonal is derived from the form of the base, which is usually quadrangular. Pyramidal system.

There are eight tetragonal forms, of which five are closed. (1) Tetragonal pyramids (figs. 78, 79) are enclosed by eight isosceles triangles, with four middle edges all in one plane, and eight polar edges. There are three kinds of this form,

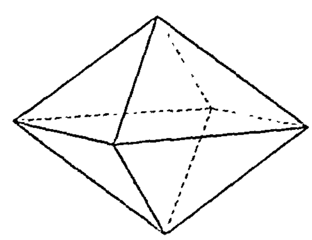


Fig. 78.

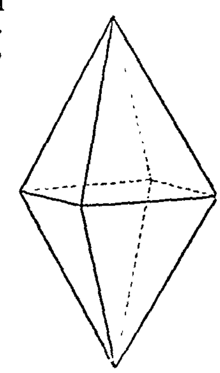


Fig. 79.

distinguished by the position of the lateral axes. In the first these axes unite the opposite angles; in the second they intersect the middle edges equally; and in the third they lie in an intermediate position, or divide these edges unequally,—the last being hemihedral forms. These pyramids are also distinguished as obtuse (fig. 78) or acute (fig. 79), according as the vertical angle is greater or less than in the regular octahedron. (2) Ditetragonal pyramids (fig. 80) are bounded by sixteen scalene triangles, whose base-lines are all in one

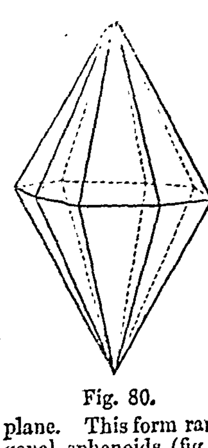


Fig. 80.

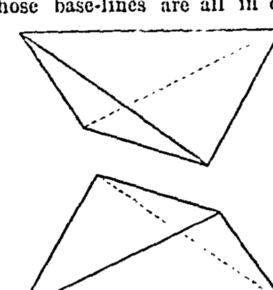


Fig. 81.

plane. This form rarely occurs except in combinations. (3) Tetragonal sphenoids (fig. 81), bounded by four isosceles triangles, are the hemihedral forms of the first variety of tetragonal pyramids. (4) The tetragonal scalenohedron (fig. 82), bounded by eight scalene triangles, whose bases rise and fall in a zigzag line, is the hemihedral form of the ditetragonal pyramid. Nos. (3) and (4) are rare. (5) The tetragonal trapezohedron is not found in minerals as a simple form. The three open forms are—(1) tetragonal prisms, bounded by four planes parallel to the principal axis, which may be either longer (fig. 83) or shorter (fig. 84) than the lateral axes; (2) ditetragonal prisms, bounded by eight similar planes; and (3) the basal pinacoid, consisting merely of two parallel faces bounding the prisms at the ends, above and below.

The various series of tetragonal crystals are distinguished from each other only by their relative dimensions. To determine these,

can be noticed. Many others more complicated will occur in the descriptive part of this article. Among holohedral combinations, the cube, octahedron, and rhombic dodecahedron are the predominant forms. In fig. 27 the cube has its angles replaced by the faces of the octahedron, which truncate the angles, and the sign of this combination is $\infty O \infty$, O. In fig. 28 this process may be regarded as having proceeded still farther, so that the faces of the octahedron nearly equal those of the cube, while in fig. 29 they now predominate; the sign, still of the same two elements, but in reverse order, is O, $\infty O \infty$. It will thus be seen that, through an increase in the amount of the abstraction of the faces of the cube, the figure gradually passes over into that of the octahedron. This may occur in all cases, and is termed the passage of the cube into the octahedron (or *vice versa*), or a "transition by decrement."

In fig. 31 the cube has its edges replaced by the faces of the rhombic dodecahedron, which truncate the edges, the sign being $\infty O \infty$, ∞O; while in fig. 32 there is the same combination, but with the faces of the cube subordinate, and hence the sign is ∞O, $\infty O \infty$. The former figure, it will be seen, has more the general aspect of the cube, the latter of the dodecahedron. Here the solid angles of the latter are truncated by the faces of the cube, and we have the passage of the cube into the dodecahedron by decrement. The same transition, through truncation or decrement, could be shown in all cases of combinations, and in both directions, the last stage of the passage into one or other form always consisting of the replacement of its solid or interfacial angles by faces of the departing figure, more or less minute. A few illustrations of this may be given, in the three most important forms.

The relationship of the tetrakishexahedron to the cube has above been stated to be, that its faces form six low quadrilateral pyramids, which rest upon or spring from the edges of the cube. (From this the form derives its trivial name of four-faced cube.) Hence these faces bevel the edges of the cube. The first stage of such bevelling (or the last stage of the truncation of the tetrakishexahedron by the faces of the cube—whichever way it may be regarded) is seen in fig. 55. As the cubic face is here dominant, the sign is $\infty O \infty$, $\infty O3$. Fig. 56 shows a somewhat similar stage

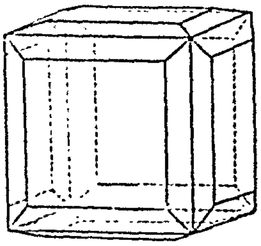


Fig. 55.

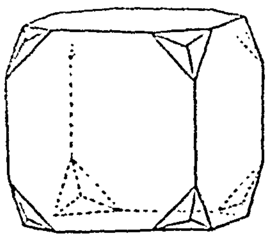


Fig. 56.

in the modification produced through the combination of the icositetrahedron with the cube. The trilateral pyramid which this form places upon the faces of the cube rests upon its solid angles, instead of, as in the last case, upon its edges; hence it is these solid angles which, in the process of decrement, it replaces by faces which form a low three-sided pyramid. The triakisoctahedron,

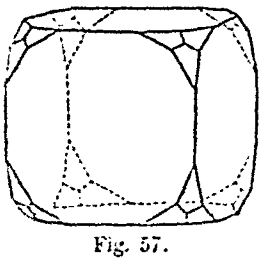


Fig. 57.

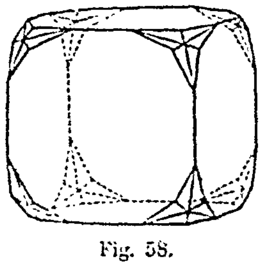


Fig. 58.

again, modifies the solid angles of the cube, as shown in fig. 57, by a low three-sided pyramid, positioned at right angles to that considered in the last combination. As the hexakisoctahedron is merely the two-faced form of that last considered, the pyramid which modifies the solid angles is, in its combination with the cube, six-sided, as in fig. 58.

As the faces of the rhombic dodecahedron truncate the edges of the octahedron, fig. 34 represents the first stage of such truncation or combination; while fig. 35 may be taken as representing the last, the faces of the octahedron being there nearly totally removed.

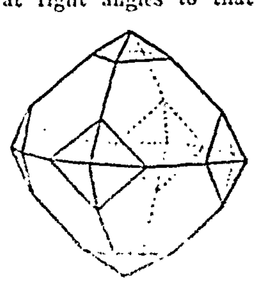


Fig. 59.

Fig. 59 shows the first stage of the passage of the octahedron into the icositetrahedron, in the truncation of the solid angles of the former form by a four-sided pyramid formed by the (6×4) faces of the latter. The faces of the octahedron truncate the three-faced solid angles of the rhombic dodecahedron. Fig. 35 shows the first stage of this truncation, while fig. 34 shows an advanced amount. The faces of the icosi-

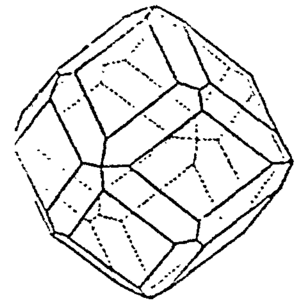


Fig. 60.

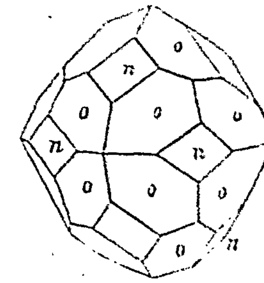


Fig. 61.

tetrahedron truncate the edges of the rhombic dodecahedron, as in fig. 60; while those of the latter truncate the unequal-angled tetragonal (or rhombic) angles of the former (fig. 61). The faces of the hexakisoctahedron bevel the edges of the rhombic dodecahedron.

While such transitions may appear indefinite, yet certain minerals have either in themselves a habit, or have at certain localities a habit, of crystallizing so markedly *in a certain stage* of these transitions as to be absolutely capable of recognition thereby.

Combinations of hemihedral or, as they have been called, semitesseral forms are of three classes:—those with holohedral forms, those in which the faces fall obliquely on one another, and those with parallel faces. Fig. 62 shows the combination of a right- Combinations of hemihedral forms.

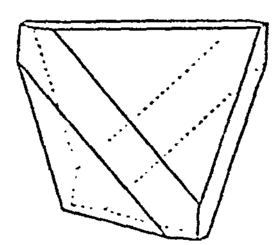


Fig. 62.

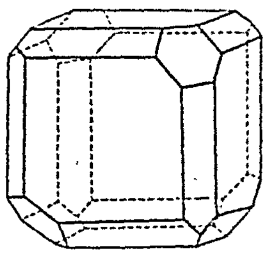


Fig. 63.

handed tetrahedron with the cube, which truncates its edges, the tetrahedron here being dominant. Fig. 63, again, shows a combination of the cubo-dodecahedron with a right-handed tetrahedron, the first or holohedral form being in this case markedly dominant.

Fig. 64 is an illustration of the second class, combinations of

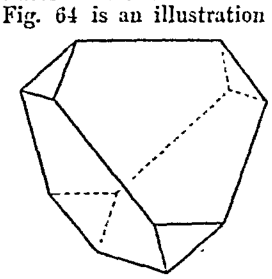


Fig. 64.

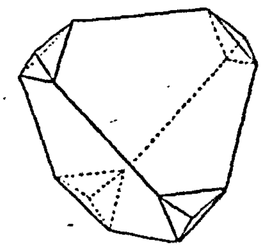


Fig. 65.

oblique-faced semitesseral forms with each other. In it a right-handed tetrahedron has its solid angles truncated by the faces of one which is left-handed; and so its sign is $\frac{O}{2}$, $-\frac{O}{2}$. Fig. 65 shows a combination of a right-handed tetrahedron with a left-

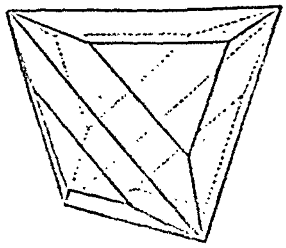
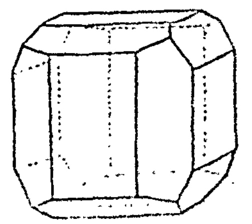


Fig. 66.



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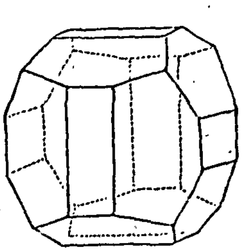
Fig. 68.

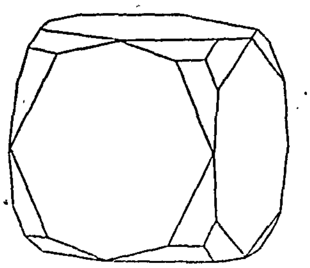
Fig. 69.

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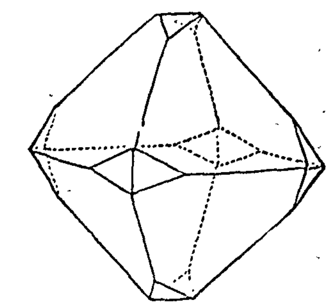
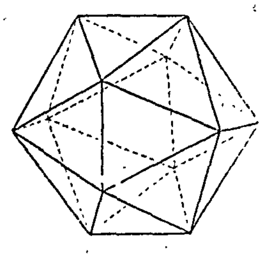


Fig. 70.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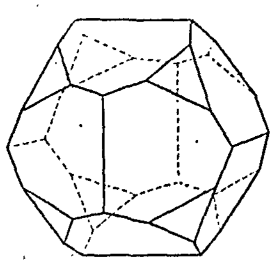
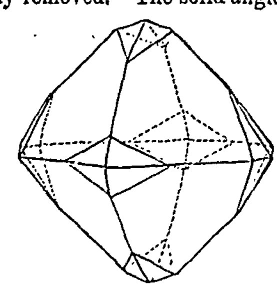


Fig. 72.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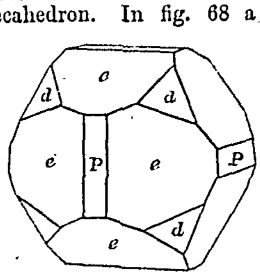
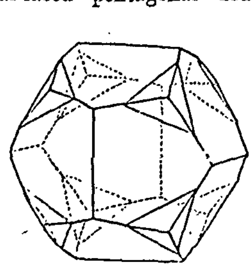


Fig. 74.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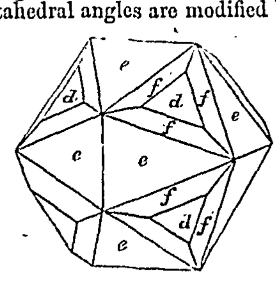
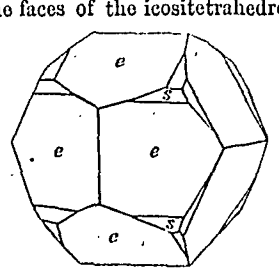


Fig. 76.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Dimetric and trimetric forms.

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Pyramidal system.

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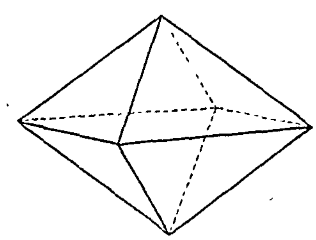
Fig. 78.

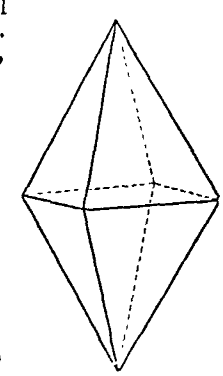
Fig. 79.

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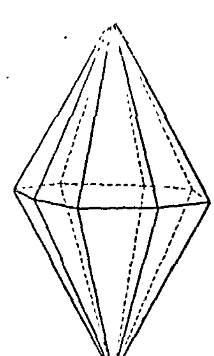
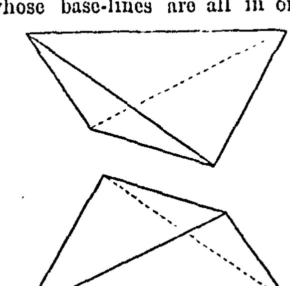


Fig. 80.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plane. This form rarely occurs except in combinations. (3) Tetragonal sphenoids (fig. 81), bounded by four isosceles triangles, are the hemihedral forms of the first variety of tetragonal pyramids. (4) The tetragonal scalenohedron (fig. 82), bounded by eight scalene triangles, whose bases rise and fall in a zigzag line, is the hemihedral form of the ditetragonal pyramid. Nos. (3) and (4) are rare. (5) The tetragonal trapezohedron is not found in minerals as a simple form. The three open forms are—(1) tetragonal prisms, bounded by four planes parallel to the principal axis, which may be either longer (fig. 83) or shorter (fig. 84) than the lateral axes; (2) ditetragonal prisms, bounded by eight similar planes; and (3) the basal pinacoid, consisting merely of two parallel faces bounding the prisms at the ends, above and below.

The various series of tetragonal crystals are distinguished from each other only by their relative dimensions. To determine these,

Primitive pyramid. one of the series must be chosen as the primary form, and for this purpose a tetragonal pyramid of the first variety, designated by P as its sign, is selected. The angle of one of its edges, especially the middle edge, found by measurement, determines its angular dimensions, whilst the proportion of the principal axis a to the

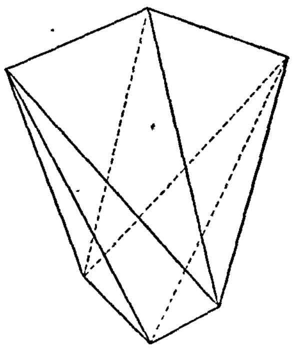


Fig. 82.

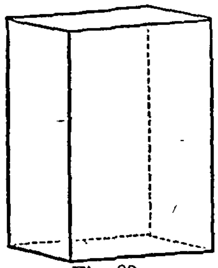


Fig. 83.

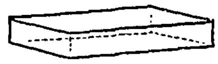


Fig. 84.

lateral axes, supposed equal to 1, gives its linear dimensions. The parameters, therefore, of each face of the fundamental form are $1 : 1 : a$.

Now if m be any (rational) number, either less or greater than unity, and if from any distance ma in the principal axis planes be drawn to the middle edge of P, then new tetragonal pyramids of the first order, but more or less acute or obtuse than P, are formed.

Derived pyramids. The general sign of these pyramids is mP, and the most common varieties $\frac{1}{2}$P, 2P, and 3P,—with the chief axis half, twice, or thrice that of P. If m becomes infinite, then the pyramid **Prism.** passes into a prism, indefinitely extended along the principal axis, and with the sign ∞P. If $m=0$, which is the case when the lateral axes are supposed infinite, then it becomes a **Pinacoid.** pinacoid, consisting properly of two basal faces open towards the lateral axes, and designated by the sign 0P. The ditetragonal pyramids are produced by taking in each lateral axis distances n greater than 1, and drawing two planes to these points from each of the intermediate polar edges. The parameters of these planes are therefore $m : 1 : n$, and the general sign of the form mPn, the most common values of n being $\frac{3}{2}$, 2, 3, and ∞. When $n=\infty$, a tetragonal pyramid of the second order arises, designated generally by mP∞, the most common in the mineral kingdom being P∞ and 2P∞. The relation of these to pyramids of the first order is shown in fig. 85, where ABBBC is the first and ACCCX the second order of pyramid. In like manner, from the prism ∞P, the ditetragonal prisms ∞Pn

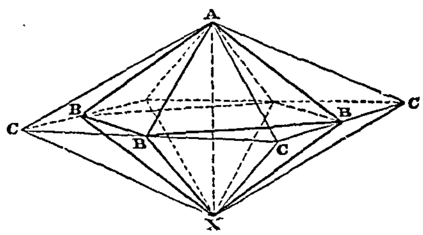


Fig. 85.

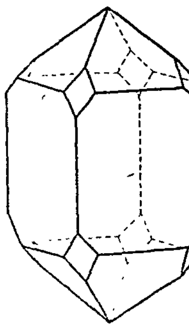


Fig. 86.

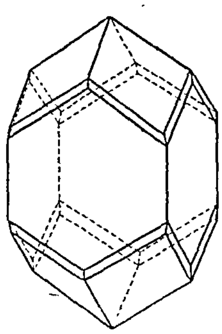


Fig. 87.

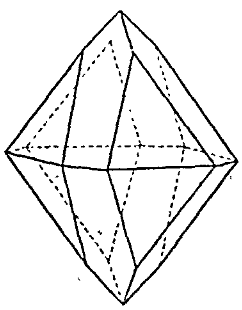


Fig. 88.

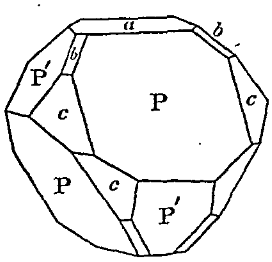


Fig. 89.

are derived, and, finally, when $n=\infty$ the tetragonal prism of the second order, whose sign is ∞P∞.

The combinations of the tetragonal system are either holohedral or hemihedral; but the latter are rare. Prisms and pinacoids must always be terminated on the open sides by other forms. Thus in fig. 86 a square prism of the first order is terminated by the primary pyramid, and has its lateral angles again replaced by another more acute pyramid of the second order, so that its sign is ∞P, P, 2P∞.

In fig. 87 a prism of the second order is first bounded by the fundamental pyramid, and then has its edges of combination replaced by a ditetragonal pyramid; its sign is ∞P∞, P, 3P3. In fig. 88 the polar edges of the pyramid are replaced by another pyramid, its sign being P, P∞. In fig. 89 a hemihedric form, very characteristic of chalcopyrite, is represented,—P and P′ being the two sphenoids, a the basal pinacoid, and b, c two ditetragonal pyramids.

Hexagonal system. III. *The Hexagonal System.*—The essential character of this system is that it has four axes,—three equal lateral axes intersecting each other in one plane at 60°, and one principal axis at right angles to these. The plane through the lateral axes, or the base, from its hexagonal form, gives the name to the system. As in the last system, its forms are either closed or open. They are divided into holohedral, hemihedral, and tetartohedral,—the last, which are rare, having only a fourth part of the faces developed. Only a few of the more common forms require to be here described.

Pyramids. The hexagonal pyramids (figs. 90, 91) are bounded by twelve isosceles triangles, and are of three kinds, according as the lateral axes fall in the angles, in the middle of the lateral edges, or in another point of these edges, the last being hemihedral forms. They are also classed as acute or obtuse, but without any precise limits. The trigonal pyramid is bounded by six triangles, and may be viewed as the hemihedral form of the hexagonal. The dihexagonal pyramid is bounded by twenty-four scalene triangles, but has never been observed alone, and rarely even in combinations. The more common prisms are the hexagonal of six sides; in these the vertical axis may be either longer than the lateral, as in fig. 92, or shorter, as in fig. 93. There are also dihexagonal, of twelve sides.

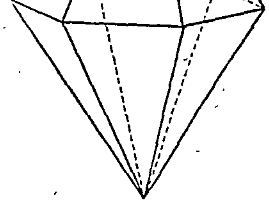


Fig. 90.

A particular pyramid P is chosen as the fundamental form of this system, and its dimensions determined either from the proportion of the lateral to the principal axis $(1 : a)$ or from the measurement of its angles. From this form (mP) others are derived exactly as in the tetragonal system. Thus dihexagonal pyramids are produced with the general sign mPn, the chief peculiarity being that, whereas in the tetragonal system n might have any rational value from 1 to ∞, in the hexagonal system it can only vary from 1 to 2, in consequence of the geometric character of the figure. When $n=2$, the dihexagonal changes into an hexagonal pyramid of the second order, whose sign is mP2. When $m=\infty$, various prisms arise from similar changes in the value of n; and when $m=0$ the basal pinacoid is formed.

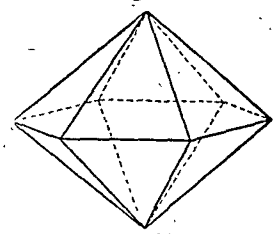


Fig. 91.

Few hexagonal mineral species form perfect holohedral combinations. Though quartz and apatite appear as such, yet properly the former is a tetartohedral, the latter a hemihedral species. In holohedral species the predominant faces are usually those of the hexagonal **Prisms.** prisms ∞P (fig. 92) and ∞P2, or of the pinacoid 0P (fig. 93); whilst the pyramids P and 2P2 are the most common subordinate forms. Fig. 94 represents the prism, bounded on the extremities by two pyramids,—one, P, forming the apex, the other, 2P2, the rhombic

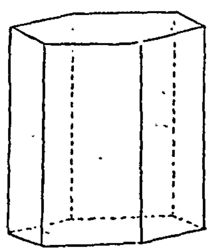


Fig. 92.

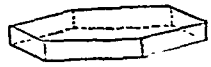


Fig. 93.

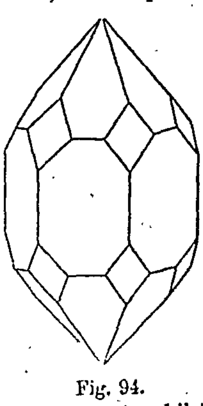


Fig. 94.

faces on the angles, or ∞P, P, 2P2. Fig. 95 is a similar form, the upper part of the pyramid being replaced by the pinacoid. In some crystals the lateral edges of the prism are replaced by the

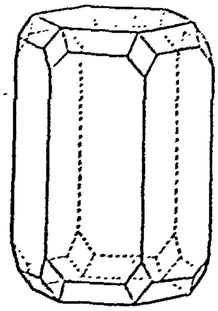


Fig. 95.

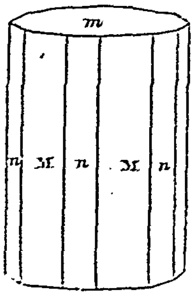


Fig. 96.

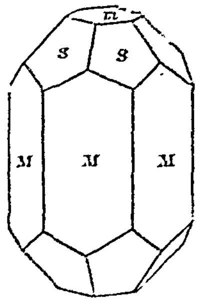


Fig. 97.

second prism ∞P2 (fig. 96), producing an equiangular twelve-sided prism, which always represents the combination ∞P, ∞P2, and cannot occur as a simple form. Figs. 97, 98 are combinations in this

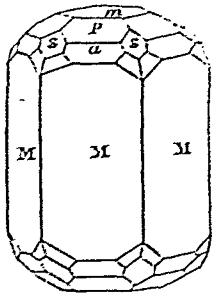


Fig. 98.

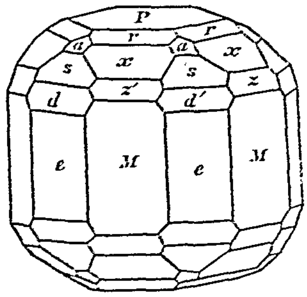


Fig. 99.

system seen in beryl. An example of a more complicated combination is seen in fig. 99, of a crystal of apatite, whose sign with the corresponding letters is ∞P(M), ∞P2(e), 0P(P), ½P(r), P(x), 2P(z), P2(a), 2P2(s), 4P2(d).

Rhombohedral forms. Hexagonal minerals frequently crystallize in those series of hemihedral forms that are named "rhombohedral," from the prevalence in them of rhombohedrons. These (figs. 100, 101) are bounded by

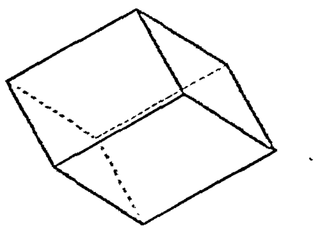


Fig. 100.

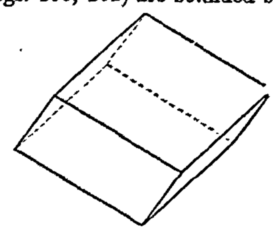


Fig. 101.

six rhombi, whose lateral edges do not lie in one plane, but rise and fall in a zigzag manner. The principal axis unites the two trigonal angles, formed by three equal plane angles; and in the most common variety the secondary axes join the middle points of two opposite edges. When the polar edges form an angle of more than 90°, the rhombohedrons are named obtuse; when of less than 90°, acute; fig. 102 represents the first, fig. 103 the second. Hexagonal scalenohedrons (fig. 104) are bounded by twelve scalene triangles, whose lateral

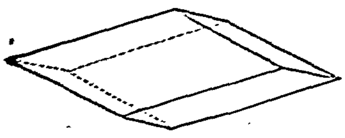


Fig. 102.

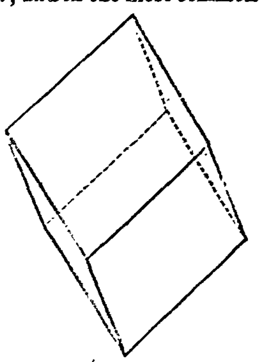


Fig. 103.

edges do not lie in one plane. The principal axis joins the two hexagonal angles, and the secondary axis the middle points of two opposite lateral edges.

The rhombohedron is derived from the first order of hexagonal pyramid by the hemihedral development of its alternate faces. Its general sign should therefore be $\frac{m\,\mathrm{P}}{2}$; but on several grounds it is found better to designate it by R or mR, and its complementary figure by $-m$R. When the prism or pinacoid arises as its limiting form, they are designated by ∞R and 0R, though in no respect changed from the limiting forms ∞P and 0P of the pyramid. The scalenohedron is properly the hemihedral form of the dihexagonal pyramid, but is more easily understood as derived from the inscribed rhombohedron mR. If the halves of the principal axis of this be multiplied by a definite number n, and then planes be drawn from the extremities of this enlarged axis to the lateral edges of the rhombohedron, as in fig. 105, the scalenohedron is constructed. It is now designated by mRn (the n on the right here referring to the chief axis), and the dihexagonal prism in this series by ∞Rn (formerly mR^n and ∞R^n).

The combinations of rhombohedral forms are very numerous, several hundreds having been described in calc-spar alone. Among the most common is the prism in combination with a rhombohedron, as seen in the twin crystal of calc-spar (fig. 106), with the sign ∞R, $-\frac{1}{2}$R, the lower half being the same form with the upper, but turned round 180°. In fig. 107 the rhombohedron mR has its polar

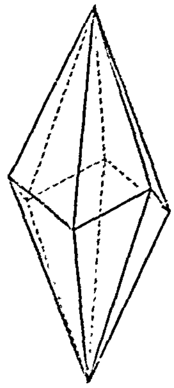


Fig. 104.

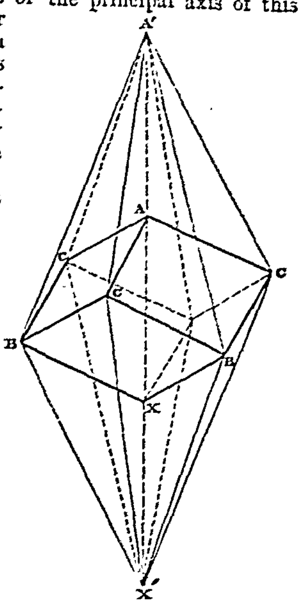


Fig. 105.

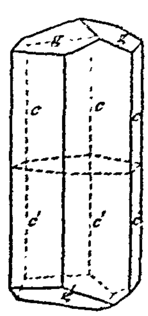


Fig. 106.

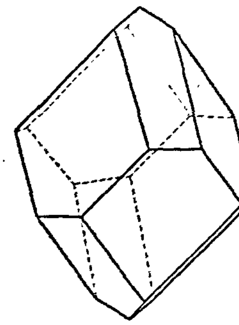


Fig. 107.

edges replaced by another rhombohedron $-\frac{1}{2}m$R, and in fig. 108 its lateral edges bevelled by the scalenohedron mRn. A more complex combination of five forms is represented in the crystal of calc-spar fig. 109, its sign, with the letters on the faces, being R^5(y), R^3(r), R(P), 4R(m), ∞R(c). Tetartohedral combinations are seen most distinctly in rock-crystal.

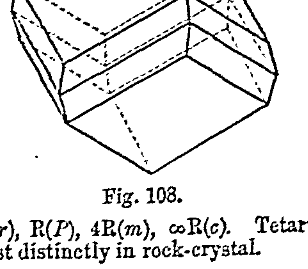


Fig. 108.

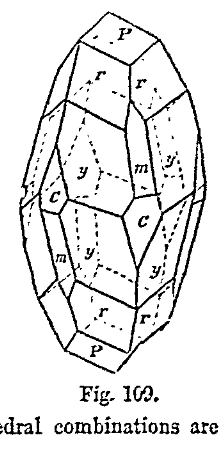


Fig. 109.

IV. *Right Prismatic or Rhombic System.*—This system is characterized by three unequal axes, all at right angles to each other. Any one of these may be assumed as the chief axis, when the others are named subordinate. The plane passing through the secondary axes, or the base, forms a rhombus, and from this one of its names is derived. As prismatic forms are most frequent (the prism standing vertically on the rhombic base), it is best defined as the right prismatic. This system comprises only a few varieties of forms that are essentially distinct, and its relations are consequently very simple.

Right prismatic system.

Pyramids. There are two closed forms. (1) The rhombic pyramids (figs. 110, 111), bounded by eight scalene triangles, whose lateral edges lie in one plane, and form a rhombus. They have eight polar edges (four acute and four more obtuse) and four lateral edges. The angles are six rhombic, the most acute at the extremities of the longest axis. (2) The rhombic sphenoids (figs. 112, 113) are bounded by four scalene

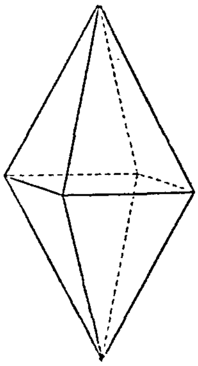


Fig. 110.

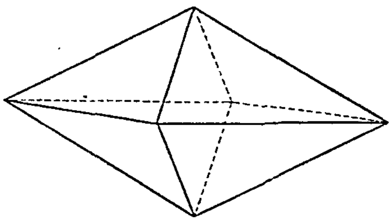


Fig. 111.

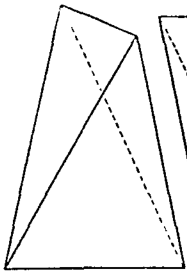


Fig. 112.

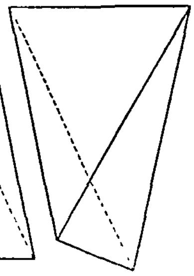


Fig. 113.

Sphenoids. triangles, with their lateral edges not in one plane, and are hemihedral forms of the rhombic pyramid. They are of very infrequent occurrence.

Prisms. The open forms, again, are rhombic prisms bounded by four planes parallel to one of the axes, which is indefinitely extended, and may be longer than the lateral, as in fig. 114, or shorter as in fig. 115. They are divided into upright (as in the above figs.) and horizontal prisms, according as either the principal or one or other of the lateral axes is supposed to become infinite. For the latter form the name doma or dome has

Domes. been used; and two kinds, the macrodome (fig. 116) and the brachydome (fig. 117), have been distinguished.

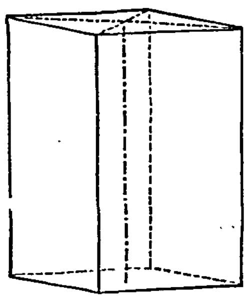


Fig. 114.

Pinacoids. Rhombic pinacoids also arise when one axis becomes $=0$ and the two others are indefinitely extended; and so we have macropinacoids (fig. 118) and brachypinacoids (fig. 119),—the qualifying term thus designating the axis to which the faces of the dome or pinacoid are parallel.


Fig. 115.

In deriving these forms from a primary, a particular rhombic pyramid P is chosen, and its dimensions determined either from the

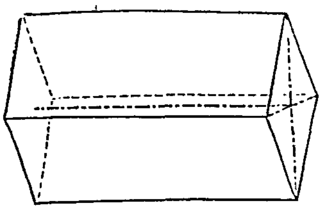


Fig. 116.

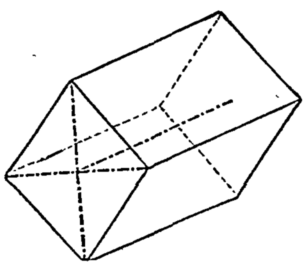


Fig. 117.

Macro- and brachy-diagonal. angular measurement of two of its edges, or by the linear proportion of its axes $a:b:c$, the greater lateral axis b being assumed equal to 1. To the greater lateral axis the name macrodiagonal is given, to the shorter that of brachydiagonal; and the two principal sections are in like manner named macrodiagonal and brachydiagonal, according to the axis they intersect. The same terms are applied throughout all the derived forms. They consequently mark only the position of the faces in respect to the axes of the fundamental crystal, and frequently of necessity without reference to the relative magnitude of the derived axes.

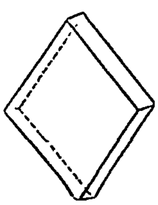


Fig. 118.


Fig. 119.

By multiplying the principal axis by any rational number m, greater or less than 1, a series of pyramids arise, whose general sign is mP, and their limits are the prism and pinacoid; the whole series being contained in this formula, $0P \ldots . mP \ldots . P \ldots . mP \ldots \ldots \infty P$,—which is the fundamental series, the lateral axes always remaining unchanged.

Derived forms. From each member a new series may, however, be developed in two directions, by increasing one or other of the lateral axes. When the macrodiagonal is thus multiplied by any number n greater than 1, and planes drawn from the distance n to the polar edges, a new pyramid is produced, named a macropyramid, with the sign $m\bar{P}n$, the mark over the P pointing out the axis enlarged. When $n=\infty$, a macrodome results, with the sign $m\bar{P}\infty$. If the shorter axis is multiplied, then brachypyramids and brachydomes are produced, with the signs $m\breve{P}n$ and $m\breve{P}\infty$. So also from the prism ∞P, on the one side, originate numerous macroprisms $\infty\bar{P}n$, with the limiting macropinacoid $\infty\bar{P}\infty$; on the other, numerous brachyprisms $\infty\breve{P}n$, with the limit form $\infty\breve{P}\infty$, or the brachypinacoid. In figs. 120, 121 the two domes are shown in their relation to the primitive pyramid.

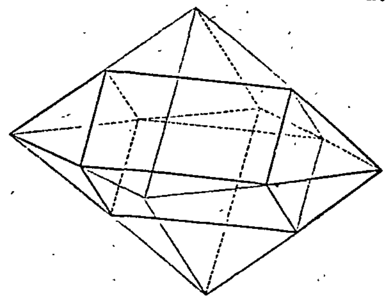


Fig. 120.

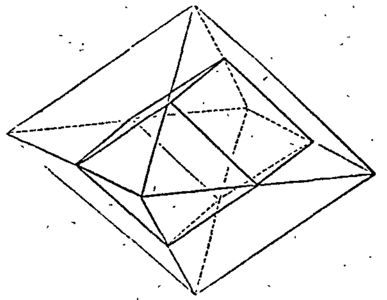


Fig. 121.

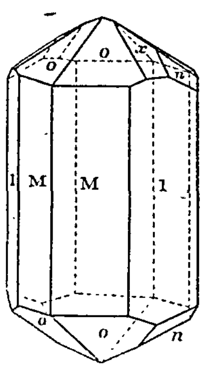


Fig 122.

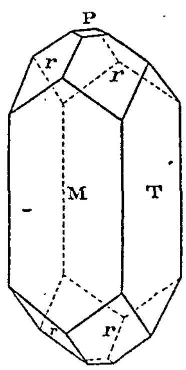


Fig. 123.

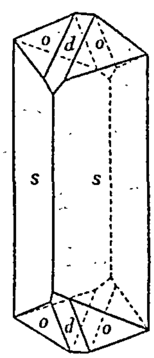


Fig. 124.

The pyramids seldom occur independent, or even as the predominant forms in a combination; sulphur, however, is an exception. Prisms or pinacoids usually give the general character to the crystal, which then appears either in a columnar or tabular or even rectangular pyramidal form. The determination of the position of these crystals, as vertical or horizontal, depends on the choice of the chief axis of the fundamental form. In the topaz crystal (fig. 122) the brachyprism and the pyramid are the predominant elements, associated with the prism, its sign and letters being $\infty\breve{P}2(l)$, $P(o)$, $\infty P(M)$. Fig. 123 of stilbite is another example, the macropinacoid $\infty\bar{P}\infty$ or M being combined with the pyramid $P(r)$, the brachypinacoid $\infty\breve{P}\infty\,(T)$, and the basal pinacoid $0P(P)$. Another instance is fig. 124 of a lievrite crystal, where the brachyprism and pyramid combine

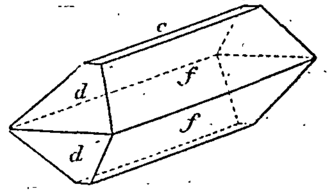


Fig. 125.

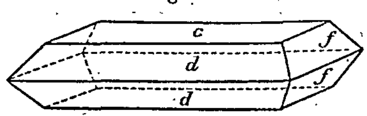


Fig. 126.

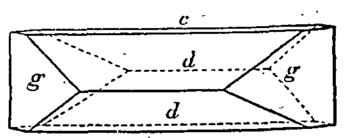


Fig. 127.

with the macrodome, or $\infty\breve{P}2$, P, $\bar{P}\infty$. The above figures are very common forms of barytes,—figs. 125 and 126 being both composed of the pinacoid 0P, a brachydome, and a macrodome, with sign 0P(*c*), $\breve{P}\infty$(*f*), $\frac{1}{2}\bar{P}\infty$(*d*). The variation in aspect arises from the predominance of different faces; and fig. 127 consists of the macrodome $\frac{1}{2}\bar{P}\infty$, the prism ∞P(*g*), and the pinacoid 0P.

Oblique prismatic system.

V. *The Oblique Prismatic System.*—This system is characterized by three unequal axes, two of which intersect each other at an oblique angle, and are cut by the third at right angles. One of the oblique axes is chosen as the chief axis, and the other axes are then distinguished as the orthodiagonal (right-angled) and clinodiagonal (oblique-angled). The same terms are applied to the chief sections, and the name of the system refers to the fact that these two planes form with the base two right angles and one oblique angle C.

Hemi-pyramidal character.

The *forms of this system approach very near to those of the right* prismatic series, but the inclination of the axis, even when almost *a right angle, gives them a* peculiar character, by which they are always readily distinguished. Each pyramid thus separates into two altogether independent forms or hemipyramids.

Prisms.

Three varieties of prism also occur—vertical, inclined, and horizontal—with faces parallel to the chief axis, the clinodiagonal, or the orthodiagonal. The horizontal prisms, like the pyramids, separate into two independent partial forms named hemiprisms or hemidomes. The inclined prisms are often designated clinodomes, the term prism being restricted to the vertical forms. Orthopinacoids and clinopinacoids are also distinguished, from their position in relation to the axes. The monoclinic pyramids (*fig.* 128) are bounded by eight scalene triangles of two kinds, four and four only being similar. Their lateral edges lie all in one plane, and the similar triangles are placed in pairs on the clinodiagonal polar edges.

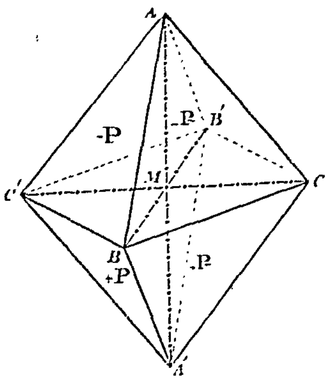


Fig. 128.

+ and − pyramids.

The two pairs in the acute angle between the orthodiagonal and basal sections are designated the positive hemipyramid, whilst the two pairs in the obtuse angles of the same sections form together the negative hemipyramid. But, as these hemipyramids are wholly independent of each other, they are rarely observed combined. More frequently each occurs alone, and then forms a prism-like figure, with faces parallel to the polar edges, and open at the extremities. Hence, like all prisms, they can only appear in combination with other forms. The vertical prisms are bounded by four equal faces parallel to the principal axis, and the cross section is a rhombus; the clinodomes have a similar form and section; whilst the horizontal prisms or domes have unequal faces, and their section is a rhomboid.

The mode of derivation of these forms closely resembles that of the rhombic series. A complete double pyramid is assumed as the fundamental form, and designated $\pm$P, in order to express the two portions of which it consists. Its dimensions are given when the proportion of its axes $a:b:c$ and the angular inclination of the oblique axes C, which is also the inclination of the orthodiagonal section to the base, are known.

The fundamental series of forms is 0P . . . . $\pm m$P . . . . $\pm$P . . . . $\pm m$P . . . . ∞P, from each of whose members, by changing the dimensions of the other axes, new forms may be again derived. Thus from $\pm m$P, by multiplying the orthodiagonal by any number n, a series of orthopyramids $\pm m\mathrm{P}^{o}n$ is produced, with the orthodomes $m\mathrm{P}^{o}\infty$ as limiting forms. The clinodiagonal produces a similar series of clinopyramids $\pm m\mathrm{P}^{c}n$, with the limiting clinodome $m\mathrm{P}^{c}\infty$ always completely formed, and therefore without the signs $\pm$ attached. From ∞P arise orthoprisms $\infty\mathrm{P}^{o}n$ and the orthopinacoid $\infty\mathrm{P}^{o}\infty$, and clinoprisms $\infty\mathrm{P}^{c}n$ and the clinopinacoid $\infty\mathrm{P}^{c}\infty$. In these signs the *o* or *c* attached to the P indicates that the orthodiagonal (*o*) or clinodiagonal (*c*) axis has been multiplied. Formerly the latter forms were enclosed in brackets, thus $(m\mathrm{P}\infty) = m\mathrm{P}\infty$.

The combinations of this system may be easily understood from their resemblance to those of the right prismatic, the chief difficulty being in the occurrence of *partial* forms, which, however, closely resemble the hemihedral forms of the previous systems. A few examples only need therefore be given.

Fig. 129 represents a very common form of gypsum crystals, $\infty\mathrm{P}^{c}\infty$, (*P*), ∞P(*f*), P(*l*). The most common form of augite is represented in fig. 130, with the sign ∞P(*M*), $\infty\mathrm{P}^{o}\infty$(*r*), $\infty\mathrm{P}^{c}\infty$(*l*), P(*s*).

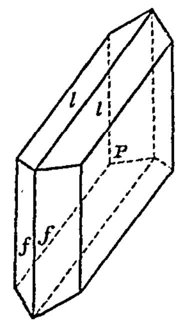


Fig. 129.

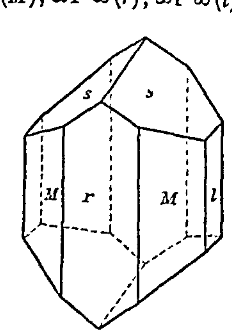


Fig. 130.

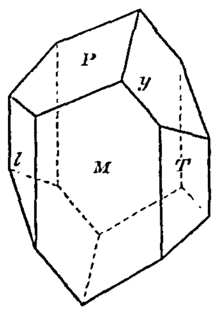


Fig. 131.

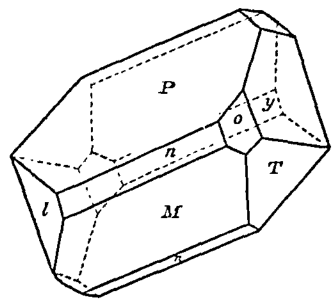


Fig. 132.

Fig. 131 is a crystal of common felspar or orthoclase, composed of the clinopinacoid $\infty\mathrm{P}^{c}\infty$(*M*), the prism ∞P(*T*), the basal pinacoid 0P(*P*), and the hemidomes $2\mathrm{P}^{o}\infty$(*y*); to which, in fig. 132 of the same mineral, the hemipyramid P(*o*) and the clinodome $2\mathrm{P}^{c}\infty$(*n*) are added.

Anorthic system.

VI. *Anorthic or Triclinic System.*—This is the least regular system, and departs the most widely, indeed almost absolutely, from symmetry of form. The axes are all unequal, and inclined at angles none of which are right angles,—so that, to determine any crystal, or series of forms, the proportion of the axes $a:b:c$, and also their angles, or those of the inclination of the chief sections, must be known. As in the previous systems, one axis is chosen as the principal axis, and the two others distinguished as the macrodiagonal and brachydiagonal axes. In consequence of the oblique position of the principal sections, this system consists entirely of partial forms wholly independent of each other, and each composed only of two parallel faces. The complete pyramid is thus broken up into four distinct quarter-pyramids, and the prism into two hemiprisms. Each of these partial forms is thus nothing more than a pair of parallel planes, and the various forms consequently mere individual faces. This circumstance renders many triclinic crystals very unsymmetrical in appearance.

Triclinic pyramids (fig. 133) are bounded by eight triangles whose lateral edges lie in one plane. They are equal and parallel two and two to each other, each pair forming, as just stated, a tetartopyramid or open form, only limited by combination with other forms, or, as we may suppose, by the chief sections. The prisms are again either vertical or inclined; the latter are named *domes*, and their section is always rhomboidal. In deriving the forms, the fundamental pyramid is placed upright with its brachydiagonal axis to the spectator, and the partial forms designated, the two upper by 'P and P', the two lower by ,P and P,, as in the figure. The further derivation now follows as in the right prismatic system, with the modifications already mentioned.

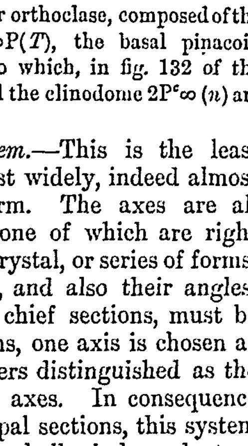


Fig. 133.

Some combinations of this system, as the series exhibited by most of the felspars, approach very near to the oblique prismatic system; whilst others, as cyanose and axinite, show great incom-

pleteness and want of symmetry. In the latter case the determination of the forms is often difficult. In the albite crystal (figs. 134, 135) P is the basal pinacoid $0P$; M the brachydiagonal pinacoid $\infty\breve{P}\infty$; s the upper right pyramid P'; l the right hemiprism $\infty P'$; T the left hemiprism $\infty' P$; and x the hemidome $'\bar{P}'\infty$. Figs. 136 and 137 are crystals of axinite, the former from Dauphiné,

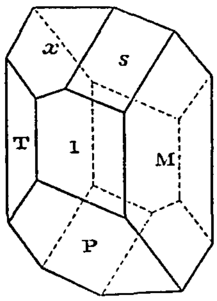


Fig. 134

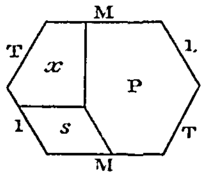


Fig. 135.

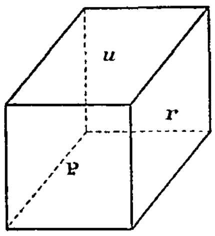


Fig. 136.

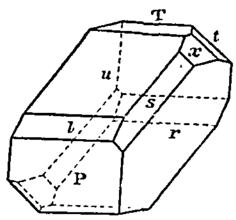


Fig. 137.

the latter from Cornwall, of whose faces the following is the development:—r the macropinacoid $\infty\bar{P}\infty$; P the left hemiprism $\infty' P$; u the left upper quarter-pyramid $'P$; l the left upper quarter-pyramid $2'P$; s the left upper partial form of the macropyramid $3'\bar{P}3$; and x the hemidome $2'P'\infty$.

The Measurement of the Angles of Crystals.

The permanence of the angular dimensions of crystals shows the importance of some accurate method of measuring their angles,—that is, the inclination of two faces to each other. Instruments for this purpose are called goniometers. Goniometers.

Two have been specially used for this purpose—the common or contact goniometer, invented by Caringeau, and the reflecting goniometer of Wollaston. The former is simply two brass rulers turning on a common centre, between which the crystal is so placed that its faces coincide with the edges of the rulers, and the angle is then measured on a graduated arc. This instrument is sufficiently accurate for many purposes and for large crystals, but for precise determination is far inferior to the reflecting goniometer. This requires smooth and even faces, but these may be very small, even the hundredth of an inch; and, as small crystals are generally the most perfect, far greater accuracy can be attained.

The reflecting goniometer is represented in fig. 138. It consists essentially of a graduated circle mm, divided on its edge into twice 180°, or more frequently into half-degrees, the minutes being read off by the vernier hh. This circle turns on an axis connected with tt, so that by turning this the circle is moved round, but it is stopped at 180°, when moving in one direction, by a spring at k. The other part of the instrument is intended to attach and adjust the crystal to be measured. The first axis of mm is hollow, and a second axis, aa, passes through it from ss, so that this and all the connected parts from b to f can be turned without moving the circle mm. The axis d passes through a hole in bc, so that it can turn the arm dc into any required position; f is a similar axis turning the arm og, and pq a fourth axis, in like manner movable in g, and with a small knob at q, to which the crystal to be measured is attached.

When about to be used, the instrument should be placed on a table, with its base horizontal (which is readily done by the screws in it), and opposite to a window at about 12 or 15 feet distance, so that its axis shall be parallel to the horizontal bars of the window. One of the upper bars of the window, and also the lower bar, or, instead of the latter, a white line on the floor or table parallel to the window, should then be chosen, in order to adjust the crystal. The observer places himself behind the instrument with the side a at his right hand. The crystal is then attached to q by a piece of wax, with the two faces to be measured upwards, and the edge of union of the faces, including the angle to be measured, as nearly as possible in the line of aa. The eye being brought near to the first face of the crystal, the axes aa and p are turned till the image of the window is seen reflected in the face with the horizontal and vertical bars in their position. The axis d is then turned through a considerable angle (say 60°), and the image of the window again sought and brought into its proper place by turning the axis f, without moving p. When this is done that face is brought into its true position, normal to d, so that no motion of d can disarrange it. Hence the image of the window may now be sought in the second face, and brought into its true position, with the horizontal bars seen horizontal, by moving the axes d and a. When this is done the crystal is properly "adjusted." The angle is measured in the following manner. First bring the zero of the circle and vernier to coincide, and then turn the inner axis a or ss, and move the eye till the image of the upper bar of the window reflected from the more distant face of the crystal coincides with the lower bar or horizontal line seen directly. Keeping the eye in its place, turn the other axis tt till the reflected image of the upper bar in the other face in like manner coincides with the lower line; the angle of the two faces is then read off on the divided circle. As the angle measured is not directly that of the faces but of the rays of light reflected from them, or the difference between the angle wanted and 180°, the circle has the degrees numbered in the reverse direction, so as to give the angle without the trouble of subtracting the one from the other.

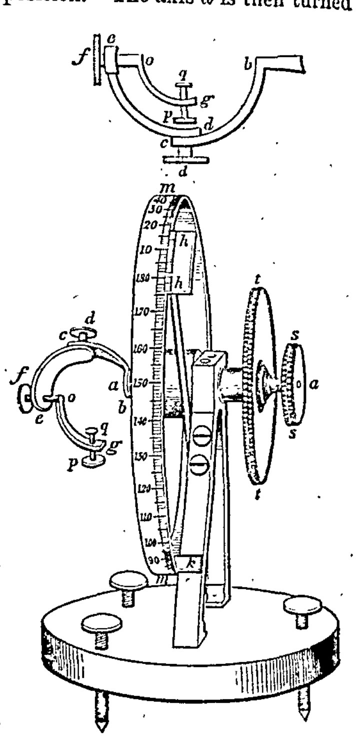


Fig. 138.

The apparatus figured is for adjusting the crystal, and is an improvement suggested by Naumann. In the original instrument the axis fo was made to push in or out in a sheath, and had a small brass plate, bent at right angles, inserted in a cleft at o, to which the crystal was attached. The crystal was adjusted as formerly by moving the plate, or the axis fo, and by slight motion of the arm dc, which should be at right angles nearly to bc when used. A very marked improvement is to have a small mirror fixed on the stand below the crystal, with its face parallel to the axis aa, and inclined at 45° to the window, when the lower line can be dispensed with, and the instrument used for various other purposes of angular measurement. Many more perfect instruments have been introduced for the purpose of insuring greater accuracy; but the simple instrument is sufficient for all purposes of determinative mineralogy, and the error from the instrument will, in most cases, be less than the actual variations in the angles of the crystals.

Departure from Geometric Simplicity and Loss of Regularity in Crystals.

Such departures may be regulated by law, or may result from an undue operation of the force of accretion in certain directions.

1. *Regular Departures from Simplicity.*—There are three varieties of this:—parallel groupings, twin forms, hemitrope forms.

Parallel Groupings.—A plurality of individuals are here arranged either so that a line which joins their centres becomes a prolongation of one or other of their crystallographic axes, or so that their axes are parallel. Crystal groups.

Fig. 20 shows the first, where cohesion sufficient for stability requires that the minute octahedra must mutually penetrate somewhat into each other. Fig. 139 shows the same in baryte. If we suppose octahedra united, the upper left-hand face of the one with the lower right-hand face of the other, there would be parallelism of their axes. Re-entering angles would, in such cases, prove a plurality of individuals, but if a number of cubes were superimposed in similar position, no such angles would occur, an elongated square prism resulting; and such arrangements, if

repeated, are linear, or, with diminishing size in the individual, acicular.

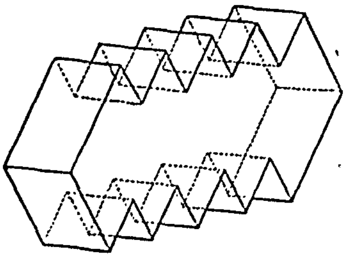


Fig. 139.

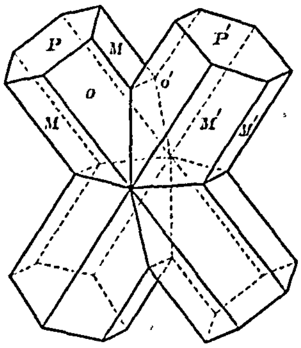


Fig. 140.

Duplex crystals.

Twins and Hemitropes.—Though closely related, formed under the operation of very similar laws, and to a certain extent passing into one another, these are not the same. In the first case a plurality of individuals must be present; in the second this is not necessary. In fig. 140 two individuals evidently intersect one another; in figs. 141, 142 one individual may be supposed to have been bisected in a certain direction, and the two halves reattached, but in a position differing in some definite manner from their relative position before the separation.

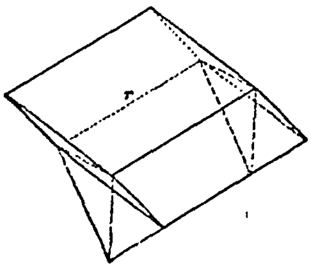


Fig. 141.

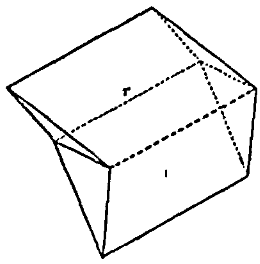


Fig. 142.

Varieties of twins.

There are four varieties of true twins: those of apposition, of intersection, of partial or completed interpenetration, and of incorporation.

The first is exemplified by spinel, as in fig. 143; the second by

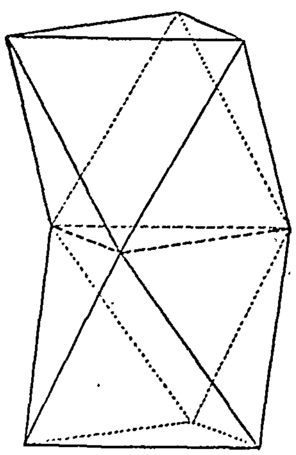


Fig. 143.

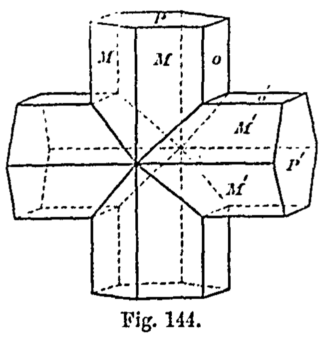


Fig. 144.

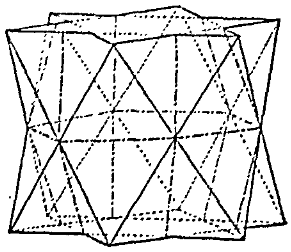


Fig. 145.

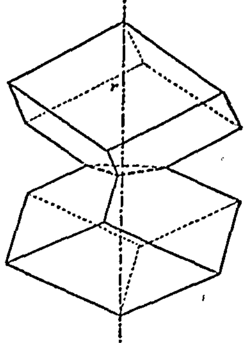


Fig. 146.

staurolite, as in fig. 144; the third by calcite, as in fig. 146, and by blende, as in fig. 145, where the two individuals of fig. 143 may be supposed to have been forced vertically into one another; and the last by quartz, as in fig. 147.

Laws of twinning.

The following are the laws of union of twins. 1. The face of union of twins, termed the "face of composition," must be either a plane which does occur in the mineral twinned, or which can occur in accordance with the fifth law of symmetry. A face of

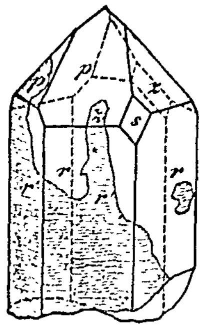


Fig. 147.

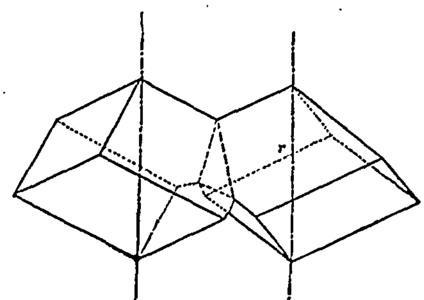


Fig. 148.

union in twins is also a face of union in hemitropes of the same mineral. 2. From the above it results that the axes of the united crystals are either parallel (fig. 148) or inclined (fig. 149). The former generally occur among hemihedric forms; and the two crystals are combined in the exact position in which they would be derived from or would reproduce the primary holohedral form. The class with oblique axes occur both in holohedric and in hemihedric forms; and the two individuals are then placed in perfect symmetry, in accordance with law 1.

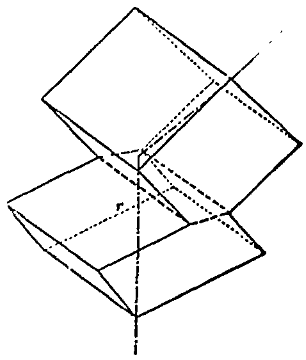


Fig. 149.

Twins are generally recognized by having *re-entering angles* (figs. 150, 151); but sometimes the crossed faces coincide in one plane, when the combination appears as a single individual (figs. 152, 153). The line of union may then be imperceptible, or it may be disclosed by the intersection of two sets of striæ (figs. 154, 155), or by some physical diversity in the characters of the two faces.

The formation of twin crystals may be again, or many times, repeated,—forming groups of three, four, twenty-four, or more. When the faces of union are parallel to each other, the crystals form

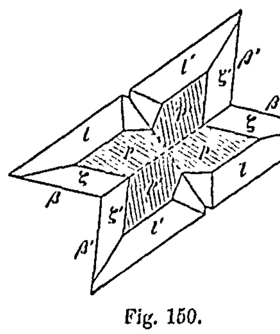


Fig. 150.

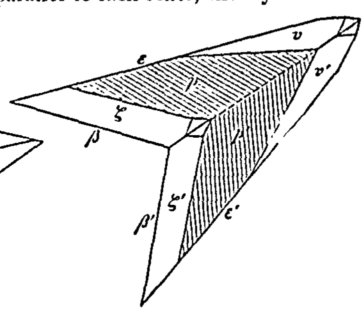


Fig. 151.

rows of indeterminate extent. When they are not parallel, they may return into each other in circles, as in rutile; or form bouquet or rosette groups, as in chrysoberyl (fig. 156); or stellate groups, as in calcite (fig. 157) and in cerussite (figs. 158, 159).

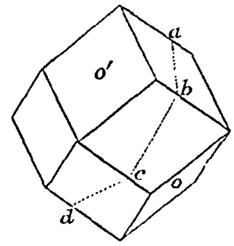


Fig. 152.

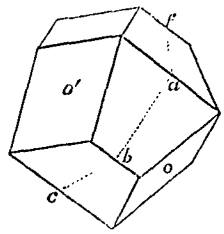


Fig. 153.

When the crystals are of different size, greater complexity results; but a number of minute crystals are frequently arranged upon a larger at those points where the angles of a single large crystal would protrude. Occasionally a simple form is twinned with a more complex one, as in chabasite (fig. 160).

Hemitropes. Hemitrope crystals we may imagine as having been formed from a single crystal, which has been cut into two halves in a particular direction, and one half turned round 180°, or 90°, or 60°. The line about which the revolution is supposed to take place is called the "axis of revolution." From the amount of turn usually being 180°, Haüy gave the name hemitrope. The position of the two

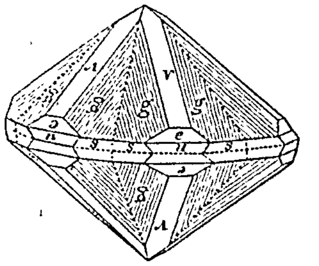


Fig. 154.

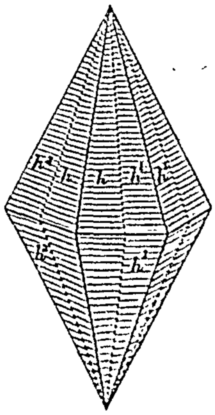


Fig. 155.

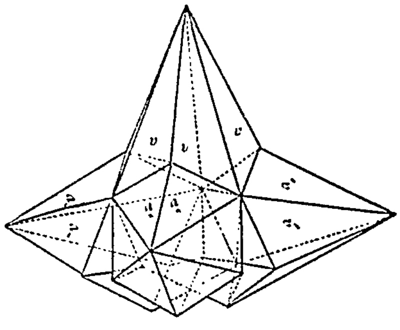


Fig. 157.

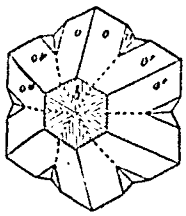


Fig. 156.

halves in this case resembles that of an object and its image in a mirror, whose surface then would represent the plane of reunion.

Laws of hemitropism. The following are the laws of hemitropes. The axis of revolution is always a possible crystallographic line,—either an axis, a line parallel to an axis, or a normal to a possible crystalline plane. The plane normal to the axis of revolution is called the twin plane; it is either an occurring or a possible plane, and usually one of the more frequently recurring planes. Both the axis and the twin plane

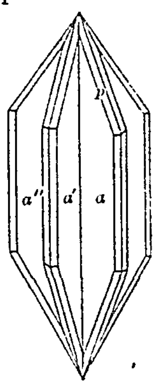


Fig. 158.

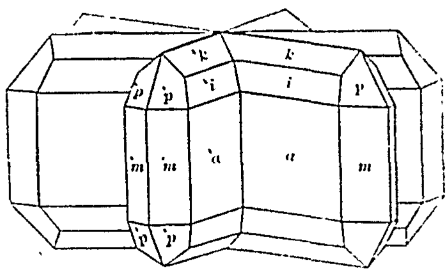


Fig. 159.

bear the same relation to both halves of the crystal in their reversed positions; consequently the parts of hemitrope crystals are symmetrical with reference to the twin plane (except in triclinic forms and some hemihedral crystals). The face of composition very frequently coincides with the twin plane; when not coinciding, the twin plane and the face of composition are generally at right angles to each other, so that the composition face is parallel to the axis of revolution. But in twins of incorporation the surfaces of composition have exercised a disturbing influence on one another, so that the surface of union is exceedingly irregular. Still in these cases the axis and the plane of twinning retain a definite position; but the face of composition, being no longer defined, is useless as a determinant.

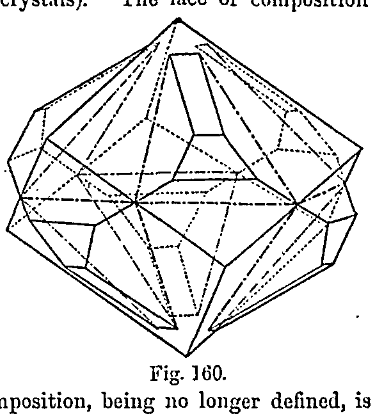


Fig. 160.

Modes of union. There are three modes in which the composition may take place in hemitropes. These may be explained by dividing a crystal into halves, with the plane of division vertical, and then turning one of the halves round.

1. One of the halves may be inverted, as if by revolution through 180° on a horizontal axis *at right angles to the plane of section*, and the two faces again united by the surfaces which were separated. Here the surfaces of union are the original ones, but the base of one of the halves has taken the place of its summit. Examples: selenite (fig. 161) and orthoclase.

2. One of the halves may be turned round through 180°, as if by revolution on *a horizontal axis, parallel to the plane of section*, and the face opposite and parallel to that of the plane of section—an originally external face—may then be applied to the other half. Here, not only has the base of one-half become a summit, but a lateral and external face of the original crystal has been thrust to its centre so as to become a face of internal union. Example: labradorite (fig. 162).

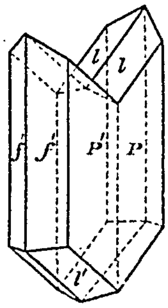


Fig. 161.

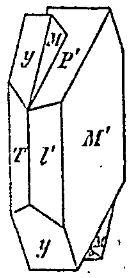


Fig. 162.

3. One of the halves may be turned round through 180°, as if by revolution *on a vertical axis*, parallel to the plane of section, the external face opposite and parallel to the plane of section becoming a face of union. Here, however, both the original summits retain their position as summits. Example: orthoclase.

The first of these modes of composition may occur in each of the systems, but it is not always apparent until disclosed by optical properties. The second is rare, and the third still more so.

In hemitrope crystals (less frequently in true twins) the halves of the crystal are frequently reduced in thickness in the direction of the ordinary twin axis; and when there is a parallel repetition of hemitropes, which frequently occurs, they are often reduced to very thin plates, not the thickness of paper, giving to the surface of the aggregate a striated structure and appearance.

Twins of cubic system. In the *cubic system* the faces of composition, both of twinning and of hemitropic revolution, are those of the cube, the dodecahedron, and the octahedron.

In the first case we have the axes of the two crystals necessarily in some cases parallel, or, more correctly, falling into one; but, as in this system all the axes are alike, or all the cubic faces similar, composition may occur along or parallel to all alike, and double or triple twins occur. We have examples in twins of the pentagonal dodecahedron (fig. 163) made up by the interpenetration of a right

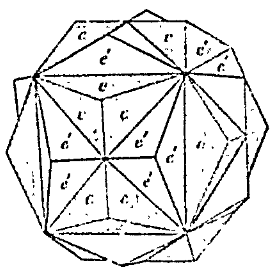


Fig. 163.

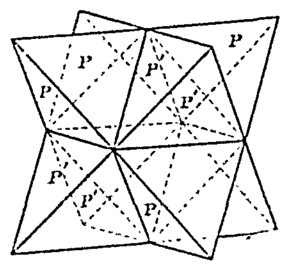


Fig. 164.

and a left (+ and −), and of the tetrahedron, as seen in pyrite and fahlerz respectively. In virtue of the position required by law 2, it will be seen that the position of the solid which is common to both intersecting crystals is in the twin of pyrite the four-faced cube, which is the holohedral form of the pentagonal dodecahedron, while in the case of the fahlerz twin (fig. 164), the common portion is an octahedron, the holohedral form of the tetrahedron.

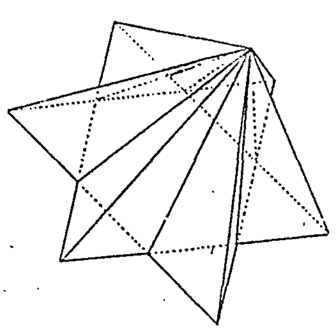


Fig. 165.

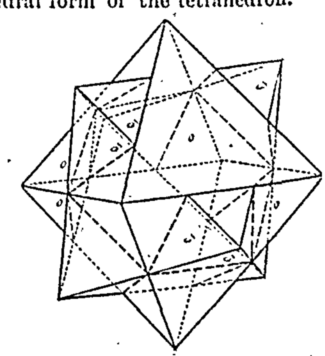


Fig. 166.

Twinning on an octahedral face is seen in the apposition twin of spinel (fig. 143), the tetrahedral twin of blende (fig. 165), the interpenetrative octahedral twin of blende seen in fig. 166, and the intersecting cubes of fluor (fig. 167).

This is also the usual twin face for hemitropes of the cubic system.

It is seen in fig. 168 of blende, where the two parts of the rhombic dodecahedron are united by it. Magnetite, spinel, and diamond

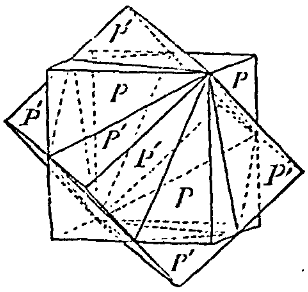


Fig. 167.

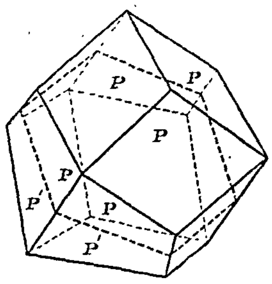


Fig. 168.

frequently occur in octahedral hemitropes of the same composition (fig. 169).

This is also the face of composition for tetartohedral hemitropes. Fig. 170 is that of the diamond. Here six of the faces of the six-

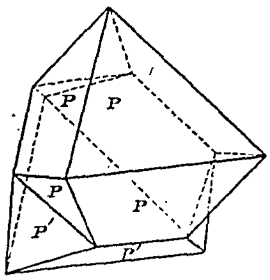


Fig. 169.

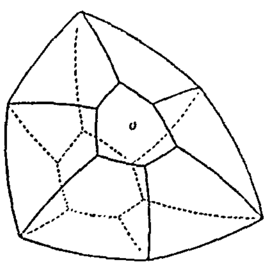


Fig. 170.

faced octahedron, with six faces diagonally opposite, form a low double six-sided pyramid (a portion of an octahedral face truncating each) through an 180° revolution of one set of these. Garnet sometimes shows both twins and hemitropes of the dodecahedron, of dodecahedral composition.

Tetragonal twins. In the *tetragonal system*, twin crystals are very uncommon, but hemitropes frequent. With parallel axes they very seldom occur, but are seen in chalcopyrite. When the axes are inclined, the plane of union is usually one of the faces of the primary pyramid; and, as these faces are all similar, composition may take place simultaneously parallel to all. Very complicated forms hence result, as seen in chalcopyrite and in cassiterite (fig. 171).

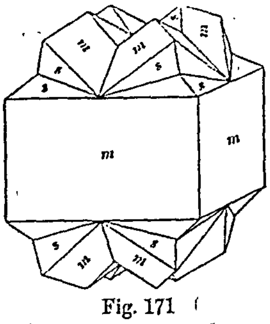


Fig. 171

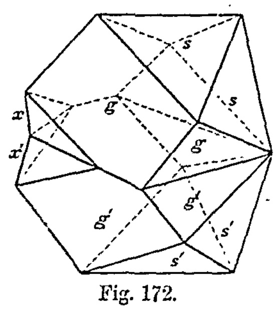


Fig. 172.

In cassiterite the plane of union is frequently one of the faces of the pyramid P∞, sometimes one of those faces that replace the polar edges of P (figs. 172 173). From the bend the latter form is termed geniculated.

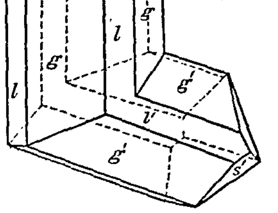


Fig. 173.

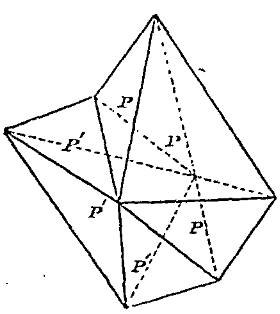


Fig. 174.

Hausmannite occurs in hemitropes of the primary P; and on the polar edges of this other twins are symmetrically repeated, a central individual appearing like a support to the others (figs. 174, 175).

Hexagonal twins. In the *hexagonal system* twins are very common among the rhombohedral (the hemihedral) and the tetartohedral forms; while hemitropes prevail among the hexagonal or holohedral forms. The twins are generally formed by the interpenetration of two rhombohedrons, a + and a −, the vertical axis being the axis of composition; as in chabasite (fig. 176), cinnabar, levyne, calcite, &c. Sometimes six or more crystals, united parallel to the prismatic planes,

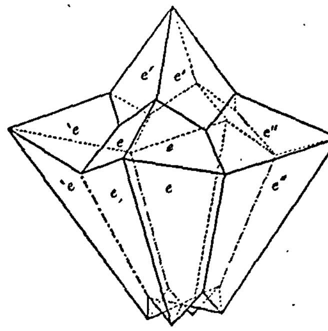


Fig. 175.

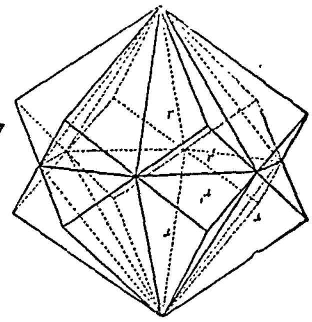


Fig. 176.

form rosettes; as in chabasite from Giant's Causeway. The almost endless stellate forms of crystals of snow are built up in this manner. Many of the most beautiful combinations to be seen among crystals result from this mode of arrangement.

Parallel groupings of hexagonal prisms also occur, as in apatite (fig. 177).

Rock crystal, in consequence of the tetartohedral character of its crystallization, exhibits twins in which the double hexagonal pyramid P may be said to be separated into two rhombohedrons *P* and *r*; these, though geometrically similar, are physi-

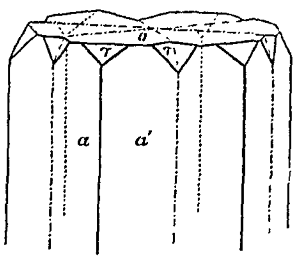


Fig. 177.

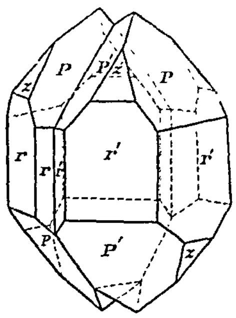


Fig. 178.

cally distinct. In fig. 178 the two individuals have not entirely interpenetrated, and might be regarded as simply grown together with parallel axes; but in fig. 147 there is so complete an interpenetration that the composite character of the crystal is only evidenced through a difference in the character of the surfaces of the two halves, which are most irregularly disposed.

The hemitropes of this system often form regular crystals, when the two halves have been united by a plane parallel to the base, so as to appear like a simple crystal, as in fig. 179. Here each end shows the forms ∞R, $-\frac{1}{2}$R, but the terminal faces appear in parallel instead of alternate position. Something of the same is seen in fig. 180, a hemitrope scalenohedron from Derbyshire. Hemitropes with the face of the primitive rhombohedron as the face of composition are also common; and they are sometimes joined by a face of $-\frac{1}{2}$R, the two axes forming an angle of 127° 34′. Occasionally a third individual is interposed in a lamellar form, as in fig. 181, where the faces of the two outer portions become parallel. This is found in some pieces of Iceland spar. When the crystals unite in a face of the primary rhombohedron, they form an angle of 89° 8′; hemitropes on this law are easily recognized by their differing so little from a right angle in the re-entering bend (figs. 182, 183).

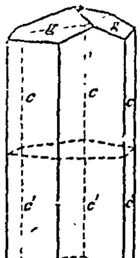


Fig. 179.

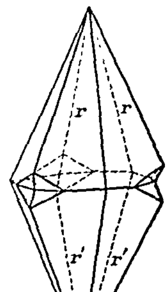


Fig. 180.

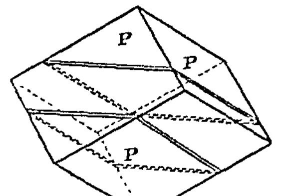


Fig. 181.

The faces which in this species act as faces of composition are exceedingly numerous; other examples are figs. 142, 146, 148, and 149.

Right prismatic twins. In the *right prismatic system* twin crystals with parallel axes are rare, but with oblique axes common, the faces of union being one of the faces of the prism ∞P. Twins of this kind occur frequently in

aragonite, cerussite, mispickel, and marcasite. In aragonite the crystals are partly interpenetrating, and partly merely in juxtaposition, as in fig. 184, where the individuals are formed by the

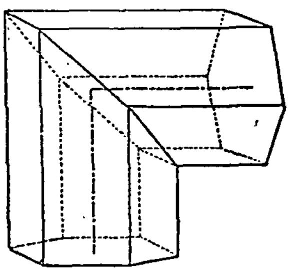


Fig. 182.

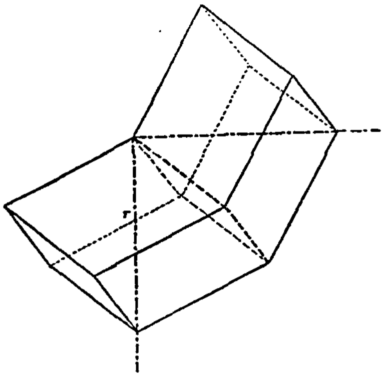


Fig. 183.

combination $\infty P(M)$, $\infty\breve{P}\infty(h)$, $\bar{P}\infty(k)$. In fig. 185 several crystals of the same combination form a series with parallel planes of union, the inner members of which are often so shortened that they form mere films, which appear as striæ on the faces $\breve{P}\infty$ and $\infty\breve{P}\infty$ of the twin.

In fig. 186 four crystals, each of the combination $\infty P, 2\breve{P}\infty$, having united in inclined planes, form a circular group, which returns into

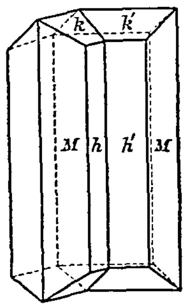


Fig. 184.

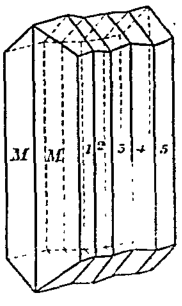


Fig. 185.

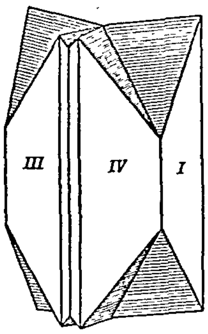


Fig. 186.

itself. Cerussite occurs in similar groups, building up a composite hexagonal crystal. It also occurs in stellate twins of two or three individuals, as in figs. 158, 159. Similar stellate combinations are also common in chrysoberyl. In staurolite, individuals of the prismatic combination ∞P, $\infty\breve{P}\infty$, $0P$ combine, either as in fig. 144 by a face of the brachydome, having their chief axes almost at right angles, or as in fig. 140 by a face of the brachypyramid $\frac{3}{2}\breve{P}\frac{3}{2}$, the chief axes and the brachypinacoids (o) of each of the crystals meeting at an angle of about 60°. This mineral, which is very frequently twinned, also forms combinations with the axes parallel (fig. 187).

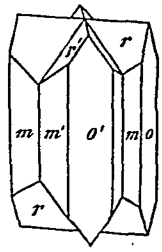


Fig. 187.

Oblique prismatic twins.

In the *oblique prismatic system*, twins are by no means so frequent as hemitropes. Twins of interpenetration with parallel axes, but the one turned as regards the other round a vertical axis, are common in orthoclase (figs. 188, 189). Such crystals are termed right-handed (fig. 188) and left-handed (fig. 189), according to the side of the crystal which has been turned. In this mineral hemitropes occur around an axis normal to M, to P, and to n (fig. 529); double twins of the last two are common (fig. 530).

Twins of hemitropes.

Harmotome and phillipsite form first hemitropes, and *then* twins of these, which are arranged sometimes as crosses and sometimes as double crosses (fig. 190). In hemitropes of gypsum the two halves are united by a face parallel to the orthodiagonal section, as in fig. 161, where the two halves have united so regularly that the faces P′, P form only one plane. In a similar manner the two halves of the augite crystal represented in fig.

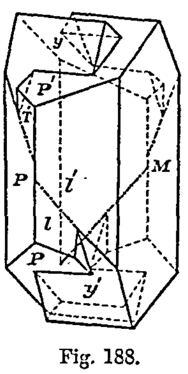


Fig. 188.

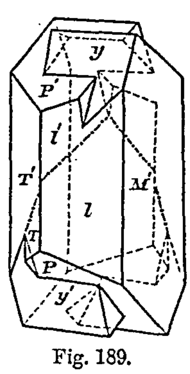


Fig. 189.

130 are in fig. 191 united so perfectly and symmetrically that the line of junction cannot be observed on the clinopinacoid. The two hemipyramids $P(s)$ (like $-P(l)$ in the gypsum crystal) form at one end of the crystal a re-entering, at the other a salient angle.

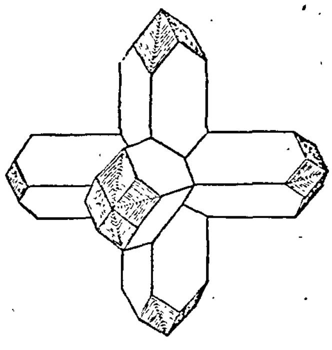


Fig. 190.

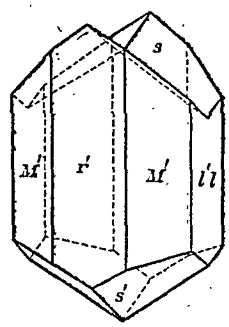


Fig. 191.

Hornblende (fig. 192) and wolfram exhibit a similar appearance. This results in the imparting a pseudo-hemimorphism to certain oblique prismatic twins, which is well seen in the twins of sphene (figs. 193 and 589), and in exalting the characteristic appearance of true hemimorphs, as seen in the twin of acmite (fig. 194). In other cases the individuals partially penetrate each other in the direction of the orthodiagonal. This mode of union is not uncommon in gypsum, and is very frequent in orthoclase. Two crystals

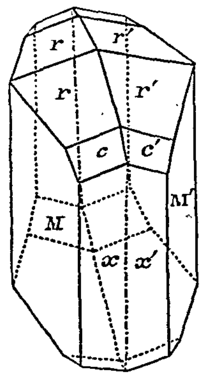


Fig. 192.

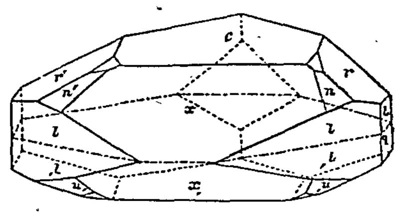


Fig. 193.

of the latter of the combination $(\infty P\infty)$, ∞P, $0P$, $2P\infty$, as in fig. 131, are often pushed into each other, as shown in fig. 195.

Anorthic twins.

In the *anorthic system* some twin formations are of great importance, *e.g.*, as a means of distinguishing the triclinic from the monoclinic species of felspar. In one variety the twin axis is the normal to the brachydiagonal chief section. But in the anorthic felspars this section is not perpendicular to the base, and consequently the two bases form on one side a re-entering, on the other a salient angle; whereas in the oblique prismatic felspars (where the brachydiagonal chief section corresponds to the clinodiagonal) no twin crystals can be produced in conformity to this law, and the two bases fall in one plane.

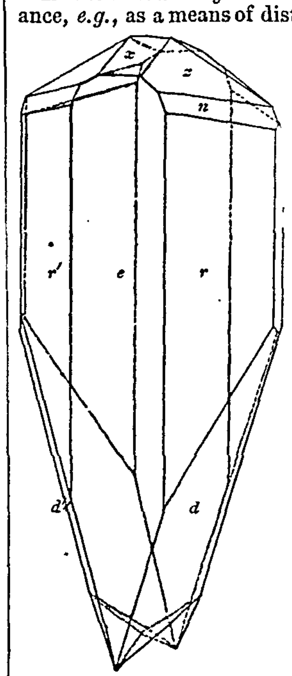


Fig. 194.

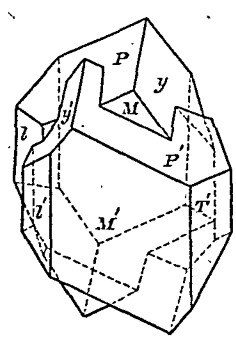


Fig. 195.

Albite and oligoclase very often exhibit such twins as in figs. 196, 197, where the very obtuse angles formed by the faces of $0P$, or P and P' (as well as those of $'\bar{P}'\infty$, or x and x'), are a very characteristic appearance, marking out this mineral at once as a triclinic species. Usually the twin formation is repeated, three or more crystals being combined, when those in the centre are reduced to mere plates. When very numerous, the surfaces P and x are covered with fine striæ, often only perceptible with a microscope. A second law observed in triclinic felspars, particularly in albite and labradorite,

is that the twin axis corresponds with that normal of the brachy-diagonal which is situated in the plane of the base. In pericline, a variety of albite, these twins appear as in fig. 198, where the two crystals are united by a face of the basal pinacoid *P*, whilst the faces of the two brachypinacoids (*M* and *M'*) form edges with very obtuse angles (173° 22'), re-entering on the one side and salient on the other. These edges, or the line of junction between *M* and *M'*, are also parallel to the edges formed by these faces and the base, or those between *M* and *P*. In this case also the twins are occasionally several times repeated, when the faces appear covered by fine striæ.

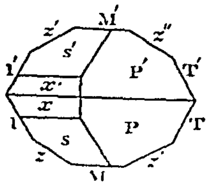


Fig. 196.

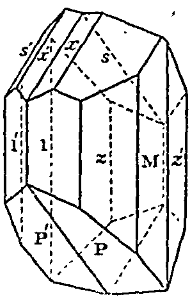


Fig. 197.

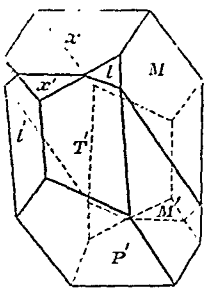


Fig. 198.

Twin growth.

Cause of the Formation of Twins and Hemitropes.—It has been shown above that the relative position of the molecules of crystals is determined by a polarity in the molecules themselves. This polarity must exist along three lines which intersect in the centre of the molecules; and unlike poles must attract each other. It has been supposed that compound crystals result from a reversion of the original polarity of the molecules of a crystal, after it has attained a certain size. Heat and electricity, resulting from movements in strata, might occasion such reversion during the formation of a crystal, and this would suffice for the explanation of hemitropes, though not directly of geniculated crystals, and still less of intersecting twins. Twins have accordingly been divided into "paragenetic" and "metagenetic." The first term is applied to the ordinarily occurring twins, in which the compound structure is supposed to have had its beginning in a nucleal compound molecule, or to have been compound in its very origin. In metagenetic twins the crystal was at first simple, but afterwards, through some change in the material furnished for its increase or possibly induced in itself, it received new layers, or an extension *in a reversed position.*

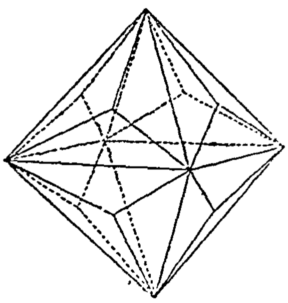


Fig. 199.

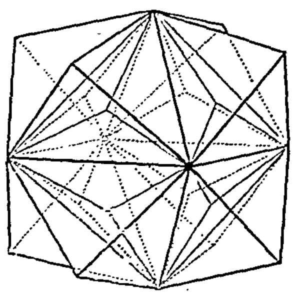


Fig. 200.

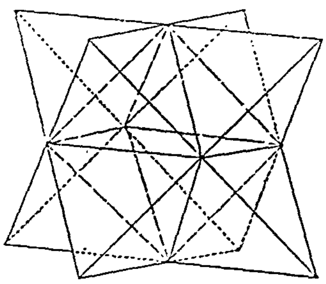


Fig. 202.

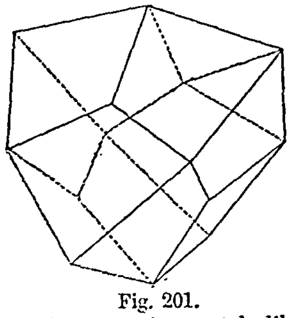


Fig. 201.

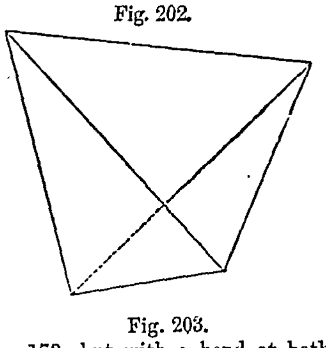


Fig. 203.

Rutile occurs in crystals like fig. 173, but with a bend at both extremities, instead of one only. Here the middle portion of the crystal is supposed to have attained a length of half an inch, and then it became geniculated simultaneously at both extremities; indeed, in this mineral such geniculations are frequently repeated until the ends are bent into one another, and produce short hexagonal prisms with central depressions or even vacuities. The repeated twinning which produces striation, as in calcite and the felspars, and the peculiar rippled structure of amethyst, are ascribed to a similar operation, acting in an oscillatory manner.

Certain intersecting twins in the cubic system may be explained simply through excessive or undue accretion of molecules along certain lines. At page 351 it was shown how the three-faced octahedron (fig. 39) was formed through an accretion of molecules upon the faces of the octahedron along axes joining the centres of its faces (those which connect the solid angles of the cube). It was also shown that when through this accretion two faces of the triakis-octahedron (fig. 199), adjacent along the edge of the octahedron, rose into one plane the rhombic dodecahedron resulted. If now accretion still goes on along the same axes, so that the trihedral pyramid rises above the level of the dodecahedral planes, fig. 200 results. This is the twin of the three-faced tetrahedron (fig. 201).

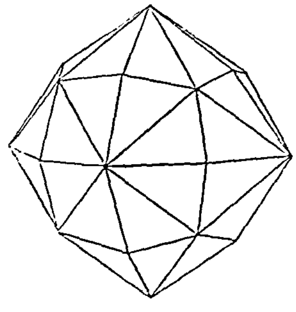


Fig. 204.

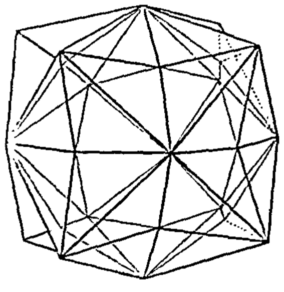


Fig. 205.

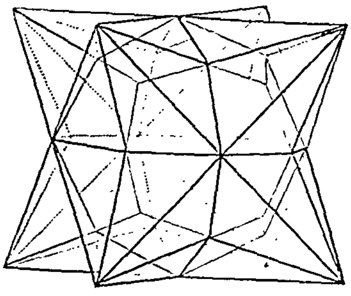


Fig. 207.

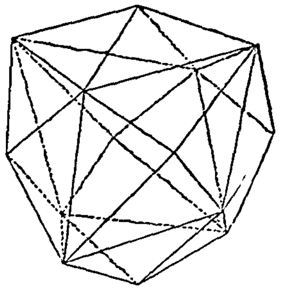


Fig. 206.

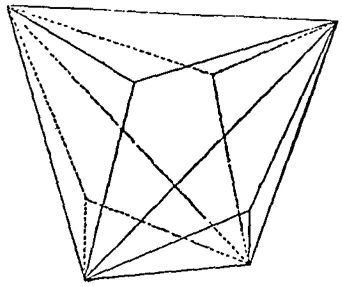


Fig. 208.

If the accretion is still along the same axes until the lateral edges of the adjacent pyramids fall into the same line, fig. 202 results; and this is the twin of the simple tetrahedron (fig. 203). Here accretion upon the faces of a complex holohedral form has produced a twin of a simple hemihedral form.

Again, starting from the six-faced octahedron (fig. 204), there is produced by the same process first fig. 205, the twin of the six-faced tetrahedron (fig. 206), and ultimately fig. 207, the twin of the three-faced tetrahedron (fig. 208).

Distortions.

2. *Departure from Regularity on Account of Undue Accretion in certain Directions.—Distortion of Crystals.*—The laws of crystallization should produce crystal forms of perfect symmetry; these laws, however, are subject, not only to the influence of other laws, but also frequently to disturbing influences which are subject to no law. Absolute symmetry, therefore, is very uncommon, crystals being generally so distorted and disguised through interference during their formation that either familiarity on the one hand or skill on the other is necessary for their recognition. As the magnitude of the angles may vary somewhat, even this guide may sometimes perplex. Hence it is necessary to be familiar with such departures from symmetry; and some of the more common are here noticed.

Of cube.

In the cubic system a cube (fig. 26), lengthened or shortened along one axis, becomes a right square prism (fig. 209), and if elongated in the direction of two axes is changed to a rectangular prism (fig. 7). Cubes of pyrites, galena, fluor-spar, &c., are generally thus distorted. It is very unusual to find a cubic crystal that is a true symmetrical cube. In some species the cube or octahedron (or other monometric form) is lengthened into a capillary

crystal or needle, as happens in red copper and pyrites. Crystals of acicular pyrites occur at the Newton-Stewart lead-mine.

An octahedron flattened parallel to two of its faces is reduced to a tabular crystal (fig. 210). If lengthened in the same direction, it takes the form in fig. 211; or if it is still further lengthened, to the obliteration of two opposite octahedral faces, it becomes an acute rhombohedron (same figure).

Of octahedron.

When an octahedron is extended in the direction of a line between two opposite edges, it has the general form of a rectangular octahedron; and still further extended, as in fig. 212, it is changed to a rhombic prism with dihedral summits. The figure represents this prism lying on its acute edge (spinel, fluor, magnetite).

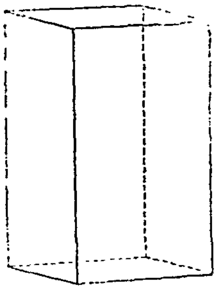


Fig. 209.

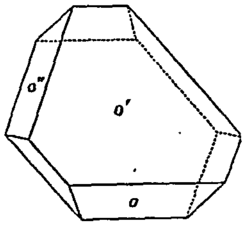


Fig. 210.

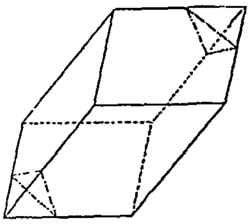


Fig. 211.

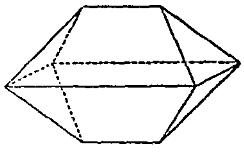


Fig. 212.

Of dodecahedron.

The dodecahedron when lengthened in the direction of the upright axis becomes a square prism with pyramidal summits (fig. 213); and when shortened along the same axis it is reduced to a square octahedron with truncated basal angles (fig. 214). Both

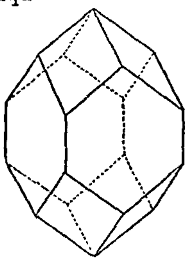


Fig. 213.

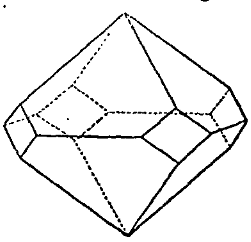


Fig. 214.

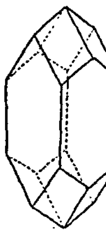


Fig. 215.

these forms are modifications of the square prism; the first mode of distortion is common in garnet, rendering it liable to be considered zircon; the second is seen in aplome, when it might be taken

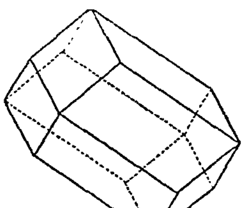


Fig. 216.

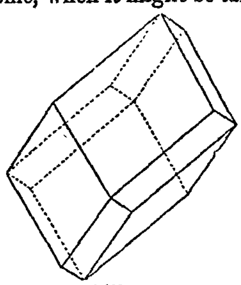


Fig. 217.

for stannite. When the first of these forms is flattened, as in fig. 215 it resembles a form of stilbite.

When a dodecahedron again is lengthened along a diagonal between the obtuse solid angles, it becomes a six-sided prism with trihedral summits, as in fig. 216; and when shortened in the same direction, it becomes a rhombohedron which has its six acute angles truncated (fig. 217). In the first case, a crystal of green garnet or uwarowite would resemble dioptase; in the latter, colourless garnet would resemble calcite.

Of trapezohedron.

The trapezohedron is exceedingly subject to distortions which frequently disguise it much. When elongated in the direction of the upright axis it becomes a double eight-sided pyramid with four-sided summits (fig. 218); a further elongation along the same axis would result in the obliteration of these summit faces, and in the production of a perfect double octagonal pyramid (fig. 219). The first of these distortions is exceedingly common in analcime and not

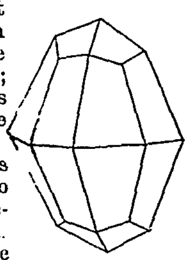


Fig. 218.

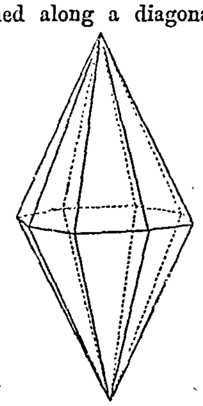


Fig. 219.

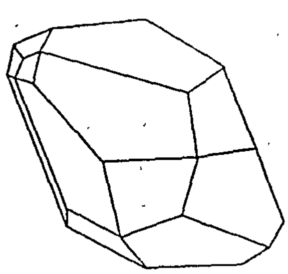


Fig. 220.

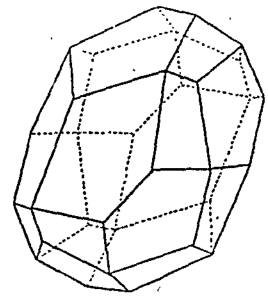


Fig. 221.

uncommon in garnet; the latter rarely occurs in analcime. Lengthened along an octahedral axis it becomes fig. 220; shortened along the same it becomes fig. 221. Both are seen in analcime.

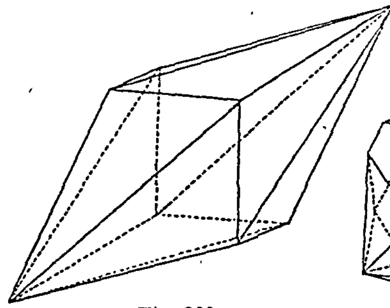


Fig. 223.

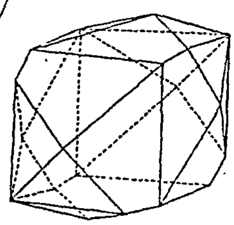


Fig. 222.

Of tetrakishexahedron.

When the tetrakishexahedron is lengthened along a single octahedral axis it assumes the form of fig. 222; still further elongated, with obliteration of one half of its planes, it becomes a scalene dodecahedron. resembling the "dog tooth" form of calcite (fig. 223). Fig. 224 is a hemihedron of this form, produced by shortening along an octahedral axis, with obliteration of all the planes which do not touch the poles of that axis.

In the case of modified crystals of this system the distortions are more complex. Fig. 225 represents a crystal of cinnamon-stone from Aberdeenshire; it is a combination of the dodecahedron and the trapezohedron. Only four dodecahedral faces remain (*d*), and those of the trapezohedron (*n*) are of unequal size. It may be best understood by regarding it as fig. 218 with the four vertical faces of fig. 213; so that it combines the distortions of both of these figures.

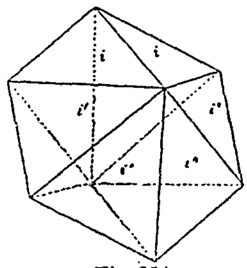


Fig. 224.

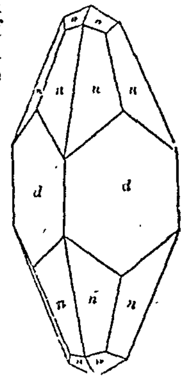


Fig. 225.

Crystals of diamond are very frequently distorted, though generally through curvatures of their faces.

Imperfections in the Surfaces of Crystals.

Of these the most important are striæ, caverns, and curvatures.

Imperfection of surfaces.

1. *Striated Surfaces.*—The parallel furrows on the surfaces of crystals are called striæ, and such surfaces are said to be striated. Each ridge on a striated surface is enclosed by two narrow planes. These planes often correspond in position to a secondary or to the primary planes of the crystal, and we may suppose these ridges to have been formed by repeated oscillation in the operation of those causes which give rise, when acting uninterruptedly, to larger planes. By this means the surfaces of a crystal are marked in parallel lines with a succession of narrow planes, meeting at angles alternately re-entering and salient, and constituting the ridges referred to. This combination of different planes in the formation of a surface has been termed an oscillation of faces.

Striation.

Cubes of pyrites are generally striated in such a way that the striæ on adjacent faces are at right angles to one another. These lines are parallel to the intersections of the primary faces with the planes of the pentagonal dodecahedron, which is the most common form of pyrites; and they have evidently resulted from an oscillation between the primary and this secondary form.

The rhombic dodecahedron is often striated parallel either with the

edges, or with the longer or the shorter diagonal of its faces. In the first case, seen in *garnet* (fig. 226), there is a passage into the six-faced octahedron; the second results from an oscillatory combination of the dodecahedron with the regular octahedron, as in magnetite; and the last with the cube, as in aplome.

Rhombohedrons of chabasite are often striated parallel to the

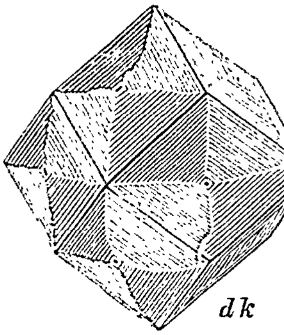


Fig. 226.

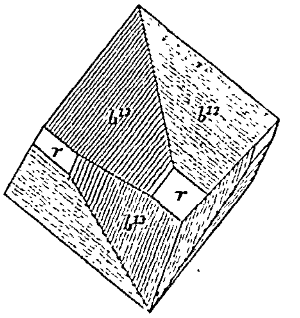


Fig. 227.

terminal edges (fig. 227), indicating an oscillatory combination between the primary faces and a secondary plane which bevels these edges.

Striation of faces is more frequent in the rhombohedral system than in any of the others. Horizontal striæ are of almost invariable occurrence in the prismatic faces of quartz, whatever be the form of the crystal. The oscillation here has taken place between the pyramidal and the prismatic faces (figs. 228, 229, 230). During its growth there seems to have been a continued effort to complete the crystal by the assumption of the terminal planes,—which effort was intermittently overcome by a preponderating one to continue the deposition of matter along its main axis. Quartz crystals, from these alternate efforts, often taper to a point, without having any regular pyramidal face.

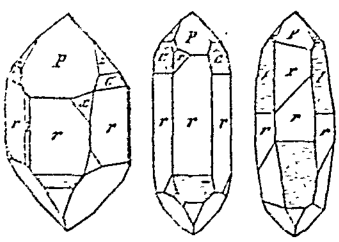


Fig. 228. Fig. 229. Fig. 230.

The lateral planes of prisms of tourmaline are very frequently convex, owing to oscillation between several lateral faces. In all such cases the interfacial angles cannot be determined, as they are lost in the rounding.

The striations on the lateral faces of foliated minerals are merely the edges of laminæ. Examples: mica and gypsum.

Cavernous faces.

2. *Cavernous Crystals.*—Crystals not unfrequently occur with a deep pyramidal depression occupying the place of each plane, as is often observed in common salt, galena (fig. 21), and sulphur. In the solution of crystals through atmospheric exposure, an approach to the same form is sometimes obtained, owing to the fact that the centres of the faces yield sooner than the edges and angles. Crystals of redruthite are often thus cavernous. Sometimes octahedrons occur with a triangular cavity, in place of each face (fig. 22). The same is met with in other forms.

Curved surfaces.

3. *Curved Surfaces.*—Curved surfaces sometimes result from the oscillatory combination already noticed. Others result from a curvature in the laminæ constituting the crystal. Crystals of diamond have convex faces, and are sometimes almost spheres. This mode of curvature, in which all the faces are equally convex, is less common than that in which a convex surface is opposite and parallel to a corresponding concave surface. Rhombohedrons of spathic iron and pearl spar are usually thus curved, as is shown in fig. 231. The saddle-shaped crystals of the same mineral (fig.

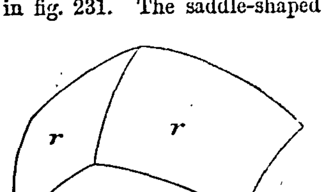


Fig. 231.

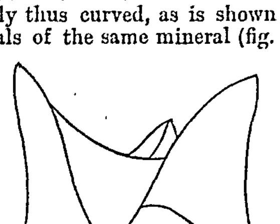


Fig. 232.

232) are remarkable instances of several reversed curvatures in the same face. A singular curvature is shown in fig. 233, of calcite. The conical crystals of brown zinc blende, and the lenticular and conical crystals of gypsum, are other examples. Crystals of quartz are sometimes curved and twisted. When this takes place in the left-handed and right-handed crystals, the twist is to the right or left according as the crystal is right- or left-handed.

The surfaces of crystals are frequently far from flat, on account of fracture, with dislocation of the several fragments, occasioned by motion in the enclosing rock, the material of which is forced, or it may be transfused, into the rents. The tourmalines and beryls (fig. 234) which occur in granitic dykes are very subject to this, the fragments being often bent as well as displaced. A more or less simultaneous effort in the crystallization of two substances may produce a structure with the external form of one, the interior of which exhibits imbedded crystals of the other, more or less perfect in their development. In *pegmatite or graphic granite*, rude crystals of felspar contain skeleton forms of quartz, of which generally only one side of the prism and two of the pyramid occur, forming a rude lettering. Similar hollow quartz forms occur imbedded in garnet, radiating from its centre (fig. 235), and roughening its surface from protrusion, without distorting its form. Totally imbedded microscopic crystals, "microliths," are, as in the latter cases, chemi-

Dislocated crystals.

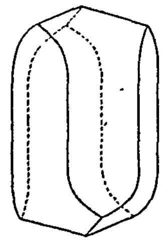


Fig. 233.

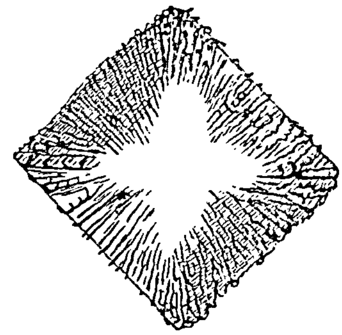


Fig. 235.

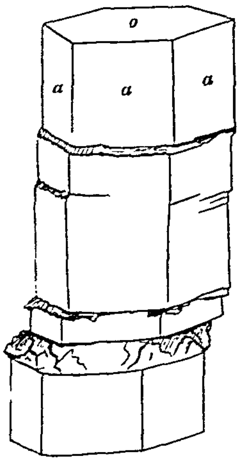


Fig. 234.

Fig. 236.

cally non-assimilable. These are frequently arranged in layers in the including crystal, as in augite and leucite. When there is a certain amount of chemical resemblance there may occur a definiteness in the arrangement; and if the enclosed substance crystallizes in a system differing from that of the mineral which includes it, the angles of the latter are more or less distorted. This is the case in "microcline," where the intrusion of a plagioclastic felspar causes some departure from the rectangularity of orthoclase. Foreign amorphous matter caught up or attaching itself to the surface of a crystal, during the process of its growth, causes lines of feeble cohesion,—as in the case of capped crystals of quartz. Here an occasional selectiveness in the sets of faces to which the foreign matter adheres seems to indicate that it has been to some extent under the influence of a polarity in its adhesion. Something of the same kind seems to have influenced the arrangement of the quartz grains caught up during the formation of the crystal of garnet shown in fig. 236. The perfect modelling of rock crystals is, however, but little interfered with by the almost numberless substances which they contain.

Aggregation of Crystals.

Crystalline aggregates which pass into amorphous masses may, in their more marked or perfect form, be assigned to an imperfect twinning.

Regular aggregates.

Crystals are often grouped in linear series, as in native copper and silver, and thus constitute long threads or reticulations. In clustered crystals those adjoining each other are generally parallel in position, and are united by a plane parallel to one of the principal sections, or to planes of common occurrence. Senarmont mentions a union in galena,

parallel to the octahedral faces, as common · and he also describes an instance where the union was parallel to the plane $3\frac{3}{2}$.

The positions of crystals on the supporting rock seem at first to be without any regularity. But by closer inspection we detect even here the same law of harmony that governs the formation of the simple and compound crystal. The various positions assumed correspond generally with the more common kinds of composition in twin crystals. This regularity is not always manifest on account of the unevenness of the surface on which they rest. In general, however, on glancing over a surface covered with crystals, a reflexion from one face will be accompanied with reflexions from the corresponding face in each of the other crystals, showing that the crystals are similarly positioned throughout.

This tendency to parallelism in the positions of associated crystals is apparent even in crystalline aggregates. In granite, for example, which is composed of felspar, quartz, and mica, the felspar crystallizations have usually a common position; that is, the corresponding extremities lie in the same direction, or nearly so. On this account granite is cleavable in one direction more easily than in others, and this direction is that of the perfect cleavage plane of the felspar; the second less perfect cleavage of the felspar permits of fracture of the rock nearly at right angles to the first; but, as there is no such third cleavage in the felspar, the workman, in fashioning the blocks of granite for paving stones, is compelled to chip or dress them off in the third direction.

Parallelism in crystal growth.

The dominant action of polarity may, moreover, give a parallel position to the main axes of different minerals belonging to the same system, when crystallizing in association, and even to those which belong to different systems. Fig. 237 is an illustration of the first of such cases, where a crystal of zircon is implanted into a crystal of xenotime, and has its main axis identically in the same line. As illustrations of the latter—a parallel position of the axes of crystals of different systems—there are records of such association in crystals of cyanite and staurolite, of muscovite and haughtonite, of albite and orthoclase. The same has been observed between crystals of rutile and specular iron,—the crystals of rutile in this case having the vertical axis in the direction of a lateral axis of the specular iron. Haidinger has observed pyroxene and hornblende crystals associated in parallel positions.

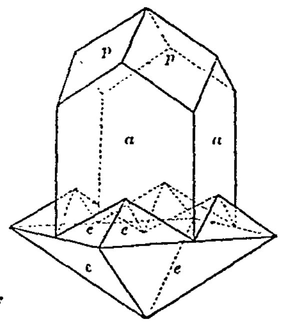


Fig. 237.

A prism of calcite terminating in the planes g (fig. 106) has been observed, in which each plane was covered with small crystals of quartz all lying symmetrically, with their pyramids pointing towards the summit of the calcite crystal. When one mineral is changed into another, a polarity of accretion is still often seen to have dominated in the arrangement. In a crystal of calcite which had been changed into a number of minute crystals of aragonite, the main axes of the latter all lay in the direction of the main axis of the original crystal of calcite.

Irregular aggregates.

Irregular Aggregation of Crystals.—Besides the regular unions now described, crystals are often aggregated in peculiar ways, to which no fixed laws can be assigned.

Thus some crystals, apparently simple, are composed of concentric crusts or shells, which may be removed one after the other, always leaving a smaller crystal like a kernel, with smooth distinct faces. Some specimens of quartz from Beeralston in Devonshire consist apparently of hollow hexagonal pyramids placed one within another. Other minerals, as fluor-spar, apatite, idocrase, heavy spar, and calc-spar, disclose a similar structure by bands of different colours. A growth rendered intermittent through the deposition of a thin layer of foreign matter is thus developed.

Many large crystals, again, appear like an aggregate of numerous small crystals, partly of the same partly of different forms. Thus some octahedrons of fluor-spar from Schlaggenwald are made up of small dark violet-blue cubes, whose projecting angles give a drusy character to the faces of the larger form. Such polysynthetic crystals, as they may be called, are very common in calc-spar.

Varieties of structure in aggregates.

Forms of Crystalline Aggregates.—Crystals have often been produced under conditions preventing the free development of their forms; and, according to the direction of the axis in which the development has been checked, they may be divided into "columnar" and "lamellar" arrangements.

The *columnar* structure is made up of a more or less fibrous arrangement; and this may be supposed to have accrued from the simultaneous growth of a multitude of crystals from a single or from closely adjacent centres of support, so that, while the crystals were free to elongate themselves in the direction of their main axis, their increase was restrained laterally, by their impact upon one another. When the surfaces of support are level, or consist of the opposing sides of a vein, the columns or fibres, frequently exceedingly delicate, are parallel, and not unfrequently they then have a silky lustre. In the latter of the above circumstances the fibres are disposed transversely to the vein. Examples: gypsum, chrysotile, satin-spar. When the surface of support is rough, or has angular projections, the fibres radiate from certain of these in all directions, producing, in a thin vein, a starlike form, whence the arrangement is called "stellular." Example: wavellite. When this takes place in an open cavity, producing brush-like forms, they are termed "radiant." Examples: antimonite, needlestone. When the points of divergent growth are so positioned that the radiating groups interlace with one another, the structure is said to be "reticulated," from its resemblance to a net. Example: tremolite. When individual members of such fibrous structure project above the general surface with acuminated extremities, they are said to be "acicular"; when the protruding columns are of uniform thickness they are termed "bacillary," or rod-like. Such terms as straight, curved, twisted-columnar, diverging, or confused-fibrous explain themselves. Such fibrous arrangements as the above may occur imbedded centrally in a rock mass, which had been the magma out of which they were formed; or they may line the inner surface of cavities, filled originally either with water or aqueous vapour. These modes of occurrence have been distinguished by Mohs as crystal groups and druses. The former includes all unions of imbedded crystals round a central nucleus; the latter those of crystals of simultaneous or regularly successive growth on a common support. In the first case, there may be spheroidal, ellipsoidal, cockscomb, or other forms, frequently seen in marcasite, pyrite, and gypsum. In the second, spheroidal forms are less rare, but are seen in the case of several of the fibrous zeolites. In such cases surfaces more or less rough are coated, and diminished in angularity, through the hemispherical forms produced by the radiation of a multitude of fibres. Certain imitative outlines thus result from the successive deposition of layers of these crystals. These forms or uniting masses are termed "globular" when nearly spherical, "botryoidal" when like bunches of grapes, "reniform" or kidney-shaped when the spheres are larger, more confluent, and less distinct, and "mammillated" when the masses are nearer to hemispheres. Mesolite occurs in globular forms; prehnite in botryoidal; hæmatite and chalcedony in reniform; and siderite and calamine in mammillated. In all the above cases the transverse fracture of such structures discloses the fibrous arrangement of the parts; but, if the growth has been intermittent, lines of deposit, concentric with the central nucleus of each sphere, are evidenced by layers of distinct colours. Fracture or separation frequently takes place, also, along such lines. In such drusy cavities—termed "geodes" when they are circular—after a certain number of such lines of deposit, grouped arrangements which have somewhat more of free crystalline development may assume other imitative forms in which there is a certain dependence on the crystallographic character of the mineral concerned. There are thus produced coralloidal or coral-like groups, fruticose or cauliflower-like groups, capillary or hair-like, and filiform or thread-like or wire-like forms. Often these groups expand in several directions, and produce arborescent, dendritic, plumose, mossy, dentiform, or other forms. Such are common among the native metals; as gold, silver, and copper. Mesolite is very frequently plumose. A "drusy crust" is the term applied to a thin rough layer of crystals, which invests either a large crystal or the surface of some other body lodged in the interior of cavities.

In the *lamellar* structure a development along the main axis would appear to have been checked, and the crystallographic force to have expended itself laterally; though this is not the invariable habit of a species under all circumstances, as exemplified by baryte. This structure consists of flat crystals, plates, or leaves. It is termed "tabular" when the plates are of uniform thickness, "lenticular" when they are thinner on the edges, "wedge-shaped" when sharp on one edge, "scaly" when the plates are thin and small, "foliaceous" when larger and easily separable; "micaceous" is also used to describe this kind of structure. It may also be curved lamellar and straight lamellar. Wollastonite, when flat lamellar, is called tabular spar; gypsum is frequently lenticular, talc scaly. Lamellar minerals when radiating from a centre often form fan-shaped, wheel-like, almond-shaped, comb-like, and other groups.

In the *granular* structure, the force of crystallization has been exerting itself along all the axes; but, from the multiplicity of crystallizing centres, there has been such mutual interference that no single individuals have been able to assume perfect or even characteristic forms. The particles in a granular structure differ much in size. When coarse, the mineral is described as coarsely granular; when fine, finely granular; if not distinguishable by the naked eye, the structure is termed impalpable. Examples of the first may be observed in granular carbonate of lime, of the

second in some varieties of specular iron, of the last in chalcedony, opal, and other species.

The above terms are indefinite, but of necessity, as there is every degree of fineness of structure in the mineral species, from perfectly impalpable, through all possible shades, to the coarsest granular. The term phanero-crystalline has been used for varieties in which the grains are distinct, and crypto-crystalline for those in which they are not discernible without the aid of a lens. Granular minerals, when easily crumbled in the fingers, are said to be friable.

The minute or crypto-crystalline minerals form aggregates somewhat similar to the above. When globular or oolitic, the minute crystals often appear to radiate from a centre, or form concentric crusts. These are often globular or nodular; as in dolomite. Somewhat similar are the stalactites and stalagmites, in which the mineral (especially rock-salt, calc-spar, malachite, hæmatite, limonite) has been deposited from a fluid dropping slowly from some overhanging body, or some rent in the roof of a cave. In this case there is generally found a long pendent cylinder or cone, the principal axis of which, generally hollow, is vertical, whilst the marginal parts are arranged at right angles to it, except where they curve round the termination of the tube, when they become hemispherical.

By far the largest masses of the mineral kingdom have, however, been produced under conditions in which a free development of their forms was excluded, and are termed amorphous. This has been the case with the greater portion of the minerals composing rocks or filling veins and dykes. The structure of these masses on the large scale belongs to geology, but some varieties of the textures, visible in hand specimens, may be noticed. The individual grains or masses have seldom any regular form, but appear round, long, or flat, according to circumstances, and as each has been more or less checked in the process of formation. Even then, however, a certain regularity in the position of the parts is often observable, as in graphic granite, where the axes of the skeleton crystals of quartz are parallel. The rock is termed massive when the grains which form it are small, or granular when they are longer and more distinct. Sometimes the rock becomes slaty, dividing into thin plates; or concretionary, forming roundish masses; at other times the interposition of some foreign substance (gas or vapour) has rendered it porous, cellular, or vesicular, giving rise to drusy cavities. These cavities are often empty, but have occasionally been more or less filled by products of change in the rock. It is named amygdaloidal when the cavities so filled have the form of an almond.

Changes of Crystalline Structure.

"Pseudomorphs" are minerals which appear under a form of crystallization which does not belong to the species. They may be recognized either by their having no cleavage, which is most usual, or by their cleavage being altogether different in direction from that of the mineral imitated. Generally they have rounded angles, rough and dull surfaces, and when broken show a granular structure. The faces of the crystal, moreover, are often covered with minute crystals of a form different from that of the mineral imitated, but which is that belonging to the substance now present. Occasionally the resemblance to real crystals is so perfect, from the perfect polish of the faces, that they are distinguished with difficulty. They may be frequently found still undergoing change.

Pseudomorphs classified. Pseudomorphs have been classed under four heads:—

1. *Pseudomorphs by Alteration.*—Formed by a gradual change of composition in a species. Of these there are two varieties: they may be pseudomorphous by loss of an ingredient, or by addition of an ingredient; change of augite to steatite is an example of the first, and of galena into anglesite is one of the second.

2. *Pseudomorphs by Substitution.*—Those formed by the replacement of a mineral which has been removed, or is gradually undergoing removal; *e.g.*, galena takes the form of pyromorphite.

3. *Pseudomorphs by Incrustation.*—Those formed through the incrustation of a crystal, which may be subsequently dissolved away. Often the cavity is afterwards filled by infiltration; *e.g.*, change of fluor to quartz.

4. *Pseudomorphs by Paramorphism.*—Those formed when a mineral passes from one dimorphous state to another; *e.g.*, change of aragonite to calcite.

These different kinds of change are not always distinguishable. In some cases a change may take place through alteration of the surface, and then, this process ceasing, the interior may be dissolved out, leaving a pseudomorph like one of incrustation; or a pseudomorph that appears to be a result of mere chemical alteration may be wholly due to substitution simply.

Again, changes of scapolite to a felspar, and of augite to uralite (hornblende), have been considered by Scheerer examples of paramorphism,—scapolite being considered dimorphous with some felspars, and augite with hornblende. But, while such paramorphic changes undoubtedly take place with aragonite, their occurrence in these silicates—which are common associates in the same rock, and must have been formed under like circumstances—is hardly probable.

Where mineral bodies have taken the form of organisms, it is more a case of molecular replacement than of true pseudomorphism.

Pseudomorphism should be understood, however, to consist, not simply in alteration of crystals, but in many instances of changes in beds of rock. Thus all serpentine, whether in mountain masses or in simple crystals, has been formed through a process of pseudomorphism—or, in more general language, of metamorphism—of olivine and augite. The same is true of other magnesian rocks, as steatitic, talcose, and chlorite slates. The crystalline rocks often offer examples of a change similar in nature. The graphite of these rocks is probably but a metamorph of some vegetable organism. Thus the subject of metamorphism, as it bears on all crystalline rocks, and that of pseudomorphism, are but branches of one system of phenomena; the chemistry of both is the same, and a knowledge of such changes is indispensable to a study of the older rock strata of the earth.

The common change of pyrites, forming the main ingredient of the upper part of metallic lodes, to earthy red or brown iron ore, thus producing the "gossan" of miners, is one of many examples of these processes now in progress. Often the gossan contains disseminated silver or gold, derived from the decomposed ores. This is a case of pseudomorphism, as truly as when a simple crystal of pyrites becomes limonite; the mode of change and its laws are the same. Again, phosphates, vanadiates, and arseniates of lead, &c., as well as carbonates and sulphates, are among the surface species, or those that occupy the upper part of metallic lodes; they are the results of alteration within those depths to which atmospheric agencies penetrate.

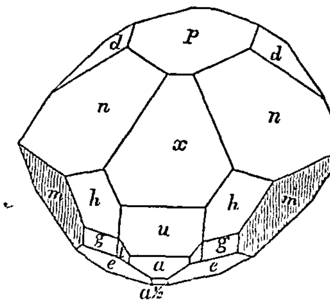


Fig. 238.

Pseudomorphs are always records of past existences, in some cases they may be the only evidence we possess of such prior existence. Figs. 238, 239 are pseudomorphs of quartz or hornstone after datholite; the measured angles of these crystals show that the imitated crystal was datholite; but that mineral does not now occur in crystals of either of these forms.

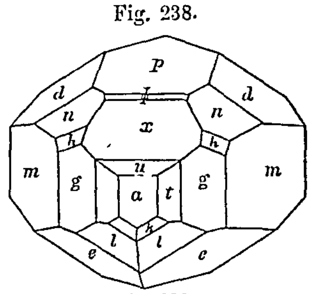


Fig. 239.

The process of petrification of organic bodies is in reality a species of pseudomorphic formation, and has been produced in all the above modes. External and internal casts of organic bodies are not uncommon. In other cases the original substance has been replaced by some mineral which has preserved, not merely the external form, but even the minutest detail of internal structure,—so that the different kinds of wood have been distinguished in their silicified trunks. The most common petrifying substances are silica and carbonate of lime. In encrinites, echinites, belemnites, and other fossils, the crystals of calc-spar often occur in very regular positions. In some varieties of petrified wood both the ligneous structure and the cleavage of the calc-spar are observable.

Different from the above are mineralized bodies, in which the original structure is still retained, but their chemical nature partially changed. In these a complete series may be often traced, as from wood or peat, through the varieties of brown coal, common coal, anthracite, and graphite.

Causes of Change.—The causes of change are the simplest and most universal operations about us:—(1) the process of gradual alteration to which some substances are liable on account of the presence of oxygen and carbonic acid in the atmosphere, and the reaction of substances thus formed on adjacent ingredients, aided or promoted by electrical currents or by heat; (2) the solvent power of ordinary waters, cold or hot, or of steam; (3) reactions, in accordance with chemical principles, of the ingredients Origin of pseudomorphs.

dissolved in these waters, or in mineral or sea waters, heated or at the ordinary temperature; (4) the action of gases exhaling from the earth; (5) changes referable to volcanic action.

Ordinary waters hold in solution, as is well known, more or less of mineral matter. When water containing carbonic acid is passed through a large number of ordinarily occurring minerals, it gives evidence of the presence of an alkali, or lime, or magnesia; and some of these minerals give the tests even with the first drops. Pure water gives with many of them a similar result, but more slowly. Limestone in forty-eight hours yields soluble ingredients to the extent of 0·4 to 1 per cent. of the whole mass. The lime, magnesia, and alkalies appear in the condition of carbonates; and the iron passes from the state of carbonate to that of peroxide during evaporation. The silicates of magnesia, lime, and manganese are especially ready in yielding to this action. Silica, however, is more soluble in ordinary than in carbonated water.

These facts illustrate two important points:—(1) that ordinary waters lying upon and filtering through the earth's crust are constantly active in dissolving and decomposing minerals and rocks, and that even species reputed indestructible are thus acted upon; and (2) that the waters are thus furnishing themselves with agents capable of effecting other chemical changes. These waters penetrate all rocks, as well as percolate through soils. Hence the action is a universal one, everywhere going on; and the results are universal. Bones, shells, corals, and animal remains generally are also sources of carbonate of lime, phosphates, and fluorides; and plants may contribute also potash and soda, and sometimes silica.

Carbonic acid is a constant ingredient of the atmosphere, and is dissolved by the rains as they descend; hence this active decomposing agent is present in all ordinary waters; but it is also a result of different mineral changes. Sulphate of iron along with vegetable matters gives oxygen to the carbon of the vegetable matter, and thus produces carbonic acid and pyrites or sulphuret of iron; and the large quantities of pyrites in coal-beds show on how grand a scale this process has taken place. Sulphate of zinc in a similar manner produces carbonic acid and blende or sulphuret of zinc. Bischof observes that the carbonic acid which has thus been eliminated must have been sufficient in quantity to make an atmosphere of carbonic acid equal in height to our present atmosphere. Again, decomposition of sulphurets produces sulphuretted hydrogen; this by the oxidating action of the atmosphere forms sulphuric acid, and the sulphuric acid acting on limestone produces gypsum, and liberates carbonic acid. Sulphurous acid is also generated in the neighbourhood of volcanoes, and rapidly becomes sulphuric acid, with the same result. Moreover, silica in waters, if aided by heat, will decompose limestone and liberate carbonic acid. Hence it is that this gas is exceedingly common in exhalations from mineral springs; indeed it occurs more or less in all waters.

The dissolving and decomposing action of carbonated waters is therefore general. The sea also partakes of this character, and, in virtue of the numerous salts which it holds dissolved, is a powerful agent in carrying on the changes to which the process leads. Such changes and the various pseudomorphs to which they give rise have to be regarded as types and evidences of vast metamorphic transformations,—processes either of decay or of reformation which have modified widespread rock-masses, and which are at the present time altering the structure of the crust of the earth. It is through a study of pseudomorphs, and of the processes which have gone to form them, that mineralogy is to become the germ from which alone the petrological department of geology can have its true development, and become a living instead of a merely speculative science.

Physical Properties of Minerals.

Characters Depending on Light.

There are few more interesting departments of science than the relations of mineral bodies to light, and the modifications which it undergoes either when passing through them or when reflected from their surface. In this place, however, we only notice these phenomena so far as they point out distinctions in the internal constitution of minerals, or furnish characters for distinguishing one species from another.

of *Lustre.*—Though the varieties of lustre admit of no precise or mathematical determination, they are of considerable value in mineralogy. One highly important distinction founded on them is that between minerals of metallic and non-metallic aspect or character. Transparency and opacity nearly coincide with this division,—the metallic minerals being almost constantly opaque, the non-metallic more or less transparent. Minerals which are perfectly opaque, and show the peculiar brilliancy and opacity of surface of polished metals, are named metallic; those which possess these properties in an inferior degree are semi-metallic; and those without these properties are non-metallic.

Lustre has reference to either the intensity or the quality of the reflected light, considered as distinct from colour. Several degrees in intensity have been named:—(1) splendent, when a mineral reflects light so perfectly as to be visible at a great distance, and lively and well-defined images are formed in its faces, as galena, specular iron, or cassiterite; (2) shining, when the reflected light is weak, and only forms indistinct and cloudy images, as heavy spar or calcite; (3) glistening, when the reflected light is so feeble as not to be observable at a greater distance than arm's length, and no longer forms an image, as talc; (4) glimmering, when the mineral held near the eye in full clear daylight presents only a number of small shining points, as red hæmatite and granular limestone. When, as in chalk or kaolin, the lustre is so feeble as to be indiscernible, the mineral is said to be dull.

In regard to the kind or quality of the lustre, the following varieties are distinguished:—(1) the metallic, seen in much perfection in native metals and their compounds with sulphur, and imperfectly in glance coal; (2) adamantine, found in beautiful perfection in the diamond, and in some varieties of blende and cerussite; a modification is metallic adamantine, as seen in wolfram and black cerussite; (3) vitreous or glassy, seen in rock crystal, or common glass, or, inclining to adamantine, in flint glass; subvitreous is seen in broken calcite; (4) resinous, when the body appears as if smeared with oil, as in pitchstone, blende, and garnet; (5) waxy, like beeswax, as seen in wax-opal and ozocerite; (6) pearly, like mother-of-pearl, seen in gyrolite, talc, heulandite; (7) silky, the glimmering lustre seen on fine fibrous aggregates like amianthus, tremolite, chrysotile, krokidolite.

These degrees and kinds of lustre are generally exhibited differently by unlike faces of the same crystal, but always similarly by like faces. The lateral faces of a right square prism may thus differ in lustre from that of a terminal face. Thus the lustre of the lateral faces of apophyllite is vitreous, while that of the terminal, at right angles thereto, is pearly; chrysotile is silky when split along the fibres, dull when at right angles to them.

The surface of a cleavage plane, in foliated minerals, generally differs in lustre from the sides; and here again in some cases the latter are vitreous, while the former is pearly, as in heulandite.

As shown by Haidinger, only the vitreous, adamantine, and metallic lustres belong to faces perfectly smooth and pure. In the first, the index of refraction of the mineral is 1·3 to 1·8; in the second, 1·9 to 2·5; in the third, above 2·5. The pearly lustre is a result of reflexion from numberless lamellæ, or cleavage planes, within a translucent mineral; and in hydrated minerals, as in the zeolites, it is the result of incipient change,—namely, a loss of water which ensues upon exposure to the atmosphere.

Colour.—This is a property which is of very inferior value. Minerals are so seldom, if ever, absolutely pure that very minute quantities of an intensely coloured impurity may impart colour to a substance inherently colourless, or overpower a feebler colour which may be its own. Colour.

Some few minerals have colour so strong or have a constitution so little susceptible of intermixture, that they retain almost unimpaired the colour special to them. Such a substance is pyrite; its brass-yellow colour may be heightened to gold-yellow by intermixture with copper sulphide, or it may be slightly bleached by arsenic; but the nature of its composition does not admit of the intrusion of ordinary colouring ingredients. The yellow of native gold, again, may be paled by impoverishment with the white of silver, down to the dull tint of electrum; but no foreign colouring matter can intrude itself into a metallic mass. Such substances as these,—native metals, sulphides, and oxides,—have colours essential to them, dependent on their constitution, and to a great extent characteristic of the species.

A second class of minerals are colourless of themselves, and thus very subject to the influence of minute quantities of foreign tinctorial impurity. These are absolutely transparent and devoid of colour when in crystals, but white and opaque when reduced to powder; as ice and snow, calcite and chalk, rock-crystal and sand. But such substances are generally coloured; "muddied" it would be called in the first case, though it is equally so with the others. Such false colour may be imparted in several ways. It may be (1) from their holding dissolved some colouring matter; (2) from mechanical mixture of colouring substances such as metallic oxides, or minute crystals ("endomorphs") of another mineral; or

(3) from chemical replacement,—the substitution of a smaller or larger quantity of a coloured isomorphous ingredient.

As illustration of the first, silica, colourless in rock-crystal, has been found of almost every tint, due frequently to volatile hydrocarbons which are dissipated by heat. Fluorite also, found of almost every shade of every colour, may possibly be to a certain extent referred here.

Quartz, felspar, and calcite are often coloured accidentally by imbedded layers of foreign "inclusions," or by "spangling endomorphs." These are mechanically mixed, so far as regards their presence in a structure of different and non-assimilable chemical composition, but crystallographically arranged. They either mark the lines of interrupted or intermittent growth; or, in the case of endomorphs, the axial positions of the minute intruding foreign crystals lie in one plane, or in the same sets of planes.

As an instance of colours introduced through definite chemical replacement, calcite may be cited. Carbonate of lime is colourless; if a portion of this be replaced by carbonate of magnesia there is a certain amount of pearly opacity; if by carbonate of manganese, of a pink tinge; if by carbonate of iron, of yellow, which may be increased through oxygen absorption and "weathering" to an ochre tint, and ultimately to a dark brown.

Sulphuret of zinc, chemically white, and mineralogically transparent, may, through metallic substitution, be found of almost all tints of yellow, orange, brown, and black. Again, hornblende, augite, and garnet,—silicates, which in their purest states of tremolite, malacolite, and water garnet are colourless,—acquire green, brown, red, and black tints from the assimilation of other metallic silicates.

Hence it would appear that a very advanced practical knowledge of the subject is necessary to enable us to avail ourselves of the information which is to be derived from this external feature.

The accidentally coloured minerals sometimes present two or more colours or tints, even in a single crystal,—very remarkable examples occurring in fluor-spar, apatite, sapphire, amethyst, tourmaline, and cyanite. This is still more common in compound minerals, on which the colours are variously arranged in points, streaks, clouds, veins, stripes, bands, or in brecciated and ruin-like forms. Some minerals again change their colour from exposure to light, the air, or damp. Then either the surface alone is affected or "tarnished," and appears covered as with a thin film, producing in some minerals, as silver and arsenic, only one colour; in others, as chalcopyrite, hæmatite, bismuth, stibine, and anthracite, various or iridescent hues, when they are said to have a pavonine lustre. Or occasionally the change pervades the whole mineral, the colour either becoming paler, or disappearing, as in chrysoprase and rose-quartz, or becoming darker, as in brown spar, siderite, and rhodonite. In a few minerals a complete change of colour takes place, as in heterosite, and in the chlorophæite of the Western Isles of Scotland, which, on exposure for a few hours, passes from a transparent yellow-green to black. These mutations are generally connected with some chemical or physical change. The tarnished colours sometimes only appear on certain faces of a crystal belonging to a peculiar form. Thus a crystal of copper pyrites (like fig. 89) has one face P′ free from tarnish; the faces *b* and *c*, close to P′, dark blue; the remainder of *c*, first violet, and then, close to P, gold-yellow.

Some crystalline minerals exhibit in certain directions a very lively play or change of colours from reflected light. It is well seen in many various hues on the cleavage-planes of labradorite, and seems produced by a multitude of very thin quadrangular pores, interposed in the mineral, like minute parallel laminæ. On the cleavage-planes of hypersthene it appears copper-red, and is occasioned by similar pores, or by numerous small brown or black laminæ of some foreign substance interposed in a parallel position between the planes of the hypersthene. The chatoyant or changing colours of the sun-stone arise from scales of hæmatite similarly interposed, and that of avanturine from scales of mica. The play of colour in the noble opal seems to be produced very nearly in the same manner as that in the labradorite. A similar opalescence is seen in certain minerals when cut in particular forms. In the sapphire, cut hemispherically over the chief axis, it appears like a star with six rays; in garnet it shows four rays; in certain varieties of chrysoberyl and of adularia it has a bluish tint; and it is also very remarkable in the cat's-eye variety of quartz. Iridescence often arises from very fine fissures, producing semicircular arches of prismatic tints, which, like the colours of thin plates in general, are referred to the interference of light.

Streak. *Streak.*—This name is applied to the appearance and the colour of the line or furrow produced in minerals by drawing the edge of a hard-tempered knife or file along their surface, or to the stain obtained by rubbing a soft mineral on such a substance as paper or porcelain. Taken along with the hardness, which may to a certain extent be determined by the same operation, it is one of the most valuable tests which we possess.

The furrow may be lustrous or it may be dull. Powder or splinters may lie along its course, or a still adherent ridge may have been merely rolled over. The furrow and the powder may each be possessed of colour, though such may not be distinguishable in the mineral, or may have a colour quite different from that of the mineral. Three illustrations of the usefulness of this test may suffice. Argentiferous gold, chalcopyrite, and pyrite, differing immensely in value, may readily be mistaken for each other. The knife, when drawn along the surface of the first, sticks in it, ruts up an adhering ridge, and leaves a shining streak of the same colour as the specimen. When drawn along the second it ruts up a trench covered with a dusty powder, which when rubbed on paper or in the hand is greenish yellow. When drawn along the third it has no effect, as pyrite is harder than the knife. Psilomelane, hæmatite, and limonite all occur in black, glossy, stalactitic forms, and have all been termed "black hæmatite." There is here also great difference in the value. The knife makes little impression on psilomelane, but leaves a blue lustrous line; it makes a blood-red line in hæmatite, and a rich ochre-yellow in limonite. Graphite and molybdenite both crystallize in hexagonal plates, both occur in the same rocks, both have a grey-black colour and a brilliant metallic lustre, both stain the hands or paper; the streak of the first—best seen on paper—is black, tending to blue; that of the last is greenish. Rough porcelain is the best material for determining the streak of soft minerals.

Diaphaneity.—Minerals, and even different specimens of the same species, vary much in this quality. Some transmit so much light that small objects can be clearly seen, or letters read, when placed behind them; such are named transparent. They are semitransparent when the object is seen only dimly, as through a cloud, and translucent when the light that passes through is so broken that the form of the object can be no longer discerned; some minerals are only thus translucent on the thinnest edges. Others transmit no light, and are named opaque. Transmission of light.

Refraction.—It has already been mentioned that most crystals—all, in fact, except those of the cubical system—exhibit the phenomena of double refraction. For a general explanation of these phenomena the reader is referred to LIGHT, vol. xv. p. 609 *sq*. Double refraction.

The direction in which there is no double refraction is named the optic axis of the crystal,—sometimes, less happily, the axis of double refraction. Now in certain minerals it is found that there is only one direction with this property, whereas in others there are two such directions; and they have in consequence been divided into uniaxal and binaxal. To the former belong all crystals of the tetragonal and hexagonal systems, to the latter all those of the other three systems. In the former the optic axis coincides with or is parallel to the crystallographic chief axis. In some uniaxal crystals the index of refraction for the extraordinary ray is greater than for the ordinary ray; and in others it is smaller. According as it is greater or less they are said to have positive (attractive) or negative (repulsive) double refraction. Optic axis.

Quartz is an example of the former, the index of refraction, according to Malus, being for $O=1\cdot5484$, for $E=1\cdot5582$; calc-spar of the latter, the index of O being $=1\cdot6543$, that of E $1\cdot4833$. The index of E is in both cases taken at its maximum.

It should be observed that the optic axes are not single lines, but directions parallel to a line, passing through every part of the crystal. It is also important to remark that this property divides crystals into three precise groups:—the cubic, with single refraction; the tetragonal and hexagonal, with double refraction, and uniaxal; those of the other three systems, also double, but binaxal. These properties are therefore of the greatest use in determining the system to which a mineral belongs.

Polarization.—Intimately connected with this property is that of the polarization of light, which affords an easier means of determining mineralogical characteristics than the direct study of double refraction. For the elements of this subject see LIGHT, vol. xv. p. 611 *sq*. Polarization.

While a consideration of the optic axes enabled us merely to arrange the systems of crystallization in three groups, the phenomena of polarization not only bear out a further subdivision of the whole into the above six systems, but disclose, in many cases, phenomena markedly special to individual species. The optical consideration of these phenomena enables us to fix three directions at

Axes of optical elasticity.

right angles to one another—called the axes of optical elasticity—such that the effect of the crystal on the luminous vibrations of the elastic ether is a maximum in one of these directions, a minimum in a second, and a maximum-minimum in the third. The length of these axes is chosen in terms of this action. In certain cases the direction of the axes of optical elasticity is different for light of different colours.

The position of these axes in relation to the crystallographic axes, and the ratios of their lengths, enable us to class all crystals as follows:—

1. Crystals of the cubic system. Here the three axes of elasticity are all equal. The refraction is simple.

2. Crystals of the tetragonal and of the rhombohedral systems. Two of the axes of optical elasticity are equal in these systems; the third is greater or less according as the crystals are negative or positive. The two equal axes lie in a plane perpendicular to the principal crystallographic axes; the third axis coincides with the principal axis.

3. Crystals of the right prismatic system. The direction of the three axes of optical elasticity coincides with the crystallographic axes, taken parallel to the diagonals of the base of the rhombohedron, and to the vertical edge of the prism (the primitive parallelepiped of Levy).

4. Crystals of the oblique prismatic system. Only one of the axes of optical elasticity coincides necessarily with the crystallographical horizontal axis, or the diagonally horizontal axis of the rhombic base, the direction of the two others not having any evident relation, *a priori*, with the inclined or diagonally inclined axis of the base, and with the vertical axis (or vertical edge of the primitive parallelepiped).

5. Crystals of the anorthic system. The three axes of optical elasticity have no relation that can be assigned *a priori* to the crystallographic axes, whatever position may be assigned to these in relation to the primitive solid.

In crystals belonging to the last three systems the three axes of elasticity are unequal.

The axes of elasticity are in general such that a ray passing through the crystal in the direction of any one of them is divided into two, which follow that direction with different velocities depending on the lengths of the other two axes. To any other direction there will in general also correspond two different velocities; but their ratio will now depend in a more complex manner on all three axes. In two directions (and only in two, if the axes are all unequal) the ratio becomes unity, or the ray is not divided. These directions are the optic axes.

The displacement of the axes of elasticity for light of different colours, already mentioned, takes place for two axes in crystals of the oblique prismatic system and for all three axes in the anorthic (*i.e.*, doubly oblique) system. In the other systems it does not occur.

Colour phenomena.

In order to follow the distinctive features of the different systems farther, it is necessary to consider the colour phenomena which they display, when examined in a beam of polarized light. Various instruments have been devised for this purpose, as, *e.g.*, the polarizing apparatus of Norrenberg, fitted with a condensing lens below and above the crystal slice, or with a low-power (3-inch) eye-piece. The polariscope of Hoffman of Paris is more efficient, but the apparatus of Descloizeaux (fig. 240), who has made this mode of investigation a special study, has the widest scope of usefulness. In this apparatus a blackened mirror is employed for polarizing the light, taking the place of a tourmaline plate, a Nicol's prism, or a bundle of thin glass. The mirror is inferior to the other two in completeness of polarizing power, and in not admitting of rotation; while it shares this defect with the last. It is, however, superior to all in extent of field, while it does not, like the first, affect white light. A Nicol's prism is used for examining or analysing the light which passes.

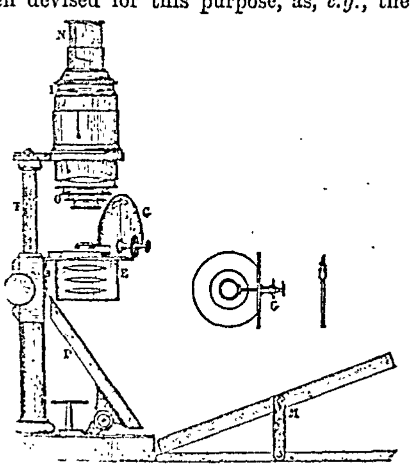


Fig. 240.—Apparatus of Descloizeaux.

The description of the many beautiful phenomena that may be observed with polarizing apparatus when applied to sections of crystals belongs to the subject of OPTICS (PHYSICAL), to which heading also we must refer for the phenomena of circular polarization.

Optic properties of composite crystals.

Double Refraction and Polarization of Composite Crystals.—In all the crystallized bodies whose action upon light we have been considering, the phenomena are identical in all parallel directions, the smallest fragment having the same property as the largest, from whatever part of the crystal it is taken. In the mineral world, however (and among the products of artificial crystallization), there occur crystals which are composed of several individual crystals whose axes are not parallel. These crystals sometimes occur in such regular symmetrical forms that mineralogists have long regarded them as simple forms; and it is probable that they would have still been so viewed if they had not been exposed to the scrutiny of polarized light.

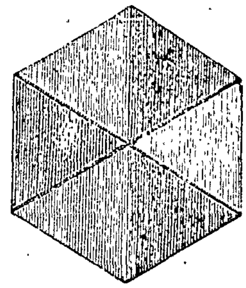


Fig. 241.

A composite structure has been observed in the case of Brazilian topaz, sulphate of potash, and apophyllite. Bipyramidal sulphate of potash, which Count Bournon supposed to be a simple crystal, was found to be a tesselated crystal, composed of three pairs of crystals of the prismatic sulphate of potash combined so that each pair had their principal axes parallel. When exposed to polarized light, each pair gave the system of binaxal rings, and when held at a distance from the eye had the tesselated appearance shown in fig. 241; each opposite pair of the triangles having the same tint.

The most remarkable of this class of minerals is the tesselated apophyllite. The examination of this body by polarized light is due to Brewster. For his results the reader is referred to his paper in the *Edinburgh Transactions*, vol. ix. p. 323.

Figs. 242, 243 are representations of the figure produced in polarized light by an internal slice of the barrel or cylindrical

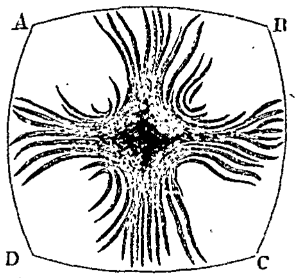


Fig. 242.

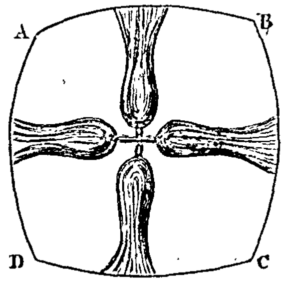


Fig. 243.

apophyllite from Kudlisaet, in Disco Island. The figures are from different specimens. The shaded part of them has only one axis of double refraction, while the four sectors have two axes. The mechanical structure of the cleavage planes resembles the optical figure even after the planes are ground.

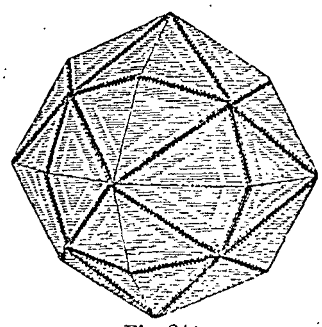


Fig. 244.

The minerals stilbite, heulandite, chabasite, and many others, are similarly complex in structure.

Crystals with Planes of Double Refraction.—Analcime, a mineral ranked among the cubical crystals, was found by Brewster to be singular in its action upon light, and to exhibit the extraordinary property of many planes of double refraction, or planes to which the double-refracting structure was related in the same manner as it is to one or two axes in other minerals. It crystallizes most commonly in the form of the icositetrahedron. If we suppose a complete crystal of it to be exposed to polarized light, it will give the remarkable figure shown in fig. 244, where the dark shaded lines represent planes in which there is neither double refraction nor polarization,—the double refraction and the tints commencing at these planes, and reaching their maximum in the centre of the space enclosed by three of the dark lines. When light is transmitted through any pair of the four planes which are adjacent to any of the three axes of the solid, it is doubly refracted, the least refracted image being the extraordinary one, and consequently the double refraction negative in relation to the axes to which the doubly-refracted ray is perpendicular. If we suppose the crystal to have the form of a

Fig. 245.

cube, the planes of double refraction will be, as in *fig.* 245, a plane passing through the two diagonals of each face of the cube.

The tints vary as the square of the distance from the nearest plane of double refraction.

Pleochroism.

Pleochroism.—Closely connected with double refraction is that property of transparent minerals named pleochroism (of many colours), in consequence of which they exhibit distinct colours when viewed by transmitted light in different directions. Crystals of the cubic system do not show this property, whilst in those of the other systems it appears in more or less perfection,—in tetragonal and hexagonal minerals as dichroism (two colours), in the rhombic and clinic systems as trichroism (three colours). In most cases these changes of colour are not very decided, and appear rather as different tints or shades than as distinct colours. The most remarkable of dichromatic minerals are the magnesian mica from Vesuvius, the tourmaline, and ripidolite; of trichromatic, iolite, andalusite from Brazil, diaspore from Schemnitz, and axinite.

In a specimen of yellow Iceland spar the extraordinary image is of an orange-yellow colour, while the ordinary image is yellowish white. Along the axis of double refraction the colour of the two pencils is exactly the same, and the difference of colour increases with the inclination of the refracted ray to the axis. This is the invariable law of the phenomena in uniaxal crystals. Sir John Herschel found several tourmalines to have a blood-red colour along the axis, and at right angles to it to be yellow-green. There can be little doubt that this property will be found in every crystal of sufficient refraction. Even if the crystal is colourless, a slight inequality in the intensity of the two images may be observed; and when it is distinctly coloured the difference of intensity is very easily seen, even when the two colours are not of a different kind.

The phenomena of dichroism are best seen in crystals with two axes of double refraction, and are well exemplified in iolite, a mineral which crystallizes in six- or twelve-sided prisms. These prisms are of a deep blue colour when seen along the axis, and of a yellowish brown colour when viewed in a direction perpendicular to it.

If *abcd* (fig. 246) is a section of the prism of iolite in a plane parallel to the axis of the prism, the transmitted light will be blue through the faces *ab* and *dc*, and yellowish brown through *ad*, *bc*, and in every direction perpendicular to the axis of the prism. If we grind down the angles *a*, *c*, *b*, *d*, so as to replace them with faces *mn*, *m'n'* and *op*, *o'p'*, inclined 31° 41' to *ad*, or to the axis of the prism, then, if the plane *abcd* passes through the optic axes, we shall observe, by transmitting polarized light through the crystal in the directions *ac*, *bd*, and subsequently analysing it, a system of rings round each of these axes. The system will exhibit the individual rings very plainly if the crystal is thin; but if it is thick, we shall observe, when the plane *abcd* is perpendicular to the plane of primitive polarization, some branches of blue and white light diverging in the form of a cross from the centre of the system of rings, or the poles of no polarization, as shown at *p* and *p'* (fig. 247), where the shaded branches represent the blue ones. The summits of the blue masses are tipped with purple, and are separated by whitish light in some specimens and yellowish light in others. The white light becomes more blue from *p* and *p'* to *o*, where it is quite blue, and more yellow from *p* and *p'* to *c* and *d*, where it is completely yellow. When the plane *abcd* is in the plane of primitive polarization, the poles *p*, *p'* are marked by spots of white light, but everywhere else the light is a deep blue.

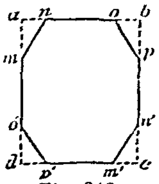


Fig. 246.

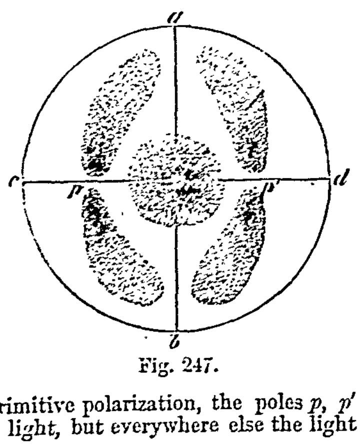


Fig. 247.

In the plane *cadb* (fig. 247) the mineral, when we look through it by common light, exhibits no other colour but yellow, mixed with a small quantity of blue, polarized in an opposite plane. The ordinary image at *c* and *d* is yellowish brown, and the extraordinary image faint blue, the former receiving some blue rays and the latter some yellow ones from *c* and *d* to *a* and *b*, where the difference of colour is still well-marked. The yellow image becomes fainter from *a* and *b* to *p* and *p'*, till it changes into blue, and the faint blue image is strengthened by other blue rays, till the intensity of the two blue images is nearly equal. As the incident ray advances from *c* and *d* to *p* and *p'*, the faint blue image becomes more intense, and the yellow one, receiving an accession of blue rays, becomes of a bluish white colour. The ordinary image is whitish from *p* and *p'* to *o*, and the extraordinary is deep blue; but the whiteness gradually diminishes towards *o*, when they are both almost equally blue.

The principal axis of double refraction in iolite is negative. The most refracted image is purplish blue, and the least refracted one yellowish brown.

Brewster found that the dichroism of several crystals is changed by heat, and that in some cases this property may be communicated to them. Babinet found that all negative crystals, such as calcareous spar, corundum (including ruby and sapphire), tourmaline, and emerald, absorb in a greater degree the ordinary ray, with the exception of beryl, apatite, and some apophyllites; while positive crystals, such as zircon, smoky quartz, sulphate of lime, and common apophyllite, absorb in a greater degree the extraordinary ray. Babinet found also that certain crystals, such as red tourmaline and ruby, transmit rays of their peculiar colour without being polarized,—in which cases the black cross of their system of rings is coloured, and this unpolarized light exists both in the ordinary and extraordinary ray.

Haidinger devised an instrument for showing and for testing the pleochroism of minerals. In *fig.* 248, *p* is an oblong cleavage-rhombohedron of Iceland spar which has two glass prisms *w*,*w* of

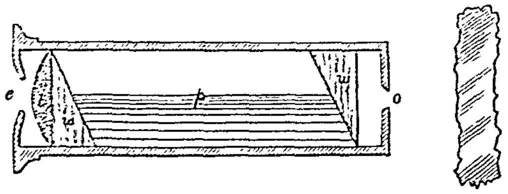


FIG. 248.—Section of Dichroiscope.

18° cemented to its ends with Canada balsam. This combination is placed in a metallic case, which has a convex lens *l* at one end and a square hole *o* about the fifteenth of an inch in width at the other. The lens is of a focal distance which shows an object held about half an inch from the square hole.

On looking through the lens and prisms two images of the square hole are seen just touching each other. The light of the one image is polarized in the plane which intersects the short diagonal of the prism; that of the other is polarized in the plane of the longer diagonal. When a pleochroic crystal or fragment is held at focal distance and examined by transmitted light, then, on the turning of the instrument bringing the polarization of its planes into coincidence with those of the crystal, the two images of the square opening will show the colours of the oppositely polarized pencils of which the light transmitted by the crystal is composed; this constitutes its pleochroism. The dichroism is then seen by looking through the crystal in one direction only, and the contrast of the two colours is made more obvious.

Phosphorescence.

Phosphorescence.—This is the property possessed by particular minerals of emitting light in certain circumstances, without combustion or ignition.

Thus some minerals appear luminous when taken into the dark, after being for a time exposed to the sun's rays or even to the ordinary daylight. Many diamonds, and also calcined barytes, exhibit this property in a remarkable degree; less so aragonite, calc-spar, and chalk. Many minerals, including the greater part of those thus rendered phosphorescent by the influence of the sun, also become so through heat. Thus some topazes, diamonds, and varieties of fluor-spar become luminous by the heat of the hand; other varieties of fluor-spar, and phosphorite, require a temperature near that of boiling water; whilst calc-spar and many silicates are only phosphorescent at from 400° to 700° Fahr.

Electricity produces phosphorescence in some minerals, as in green fluor-spar and calcined barytes. In others it is excited when they are struck, rubbed, split, or broken; as in many varieties of zinc-blende and dolomite when scratched with a quill, pieces of quartz when rubbed on each other, and plates of mica or needles of pectolite when suddenly separated.

The light emitted by phosphorescent minerals is of various tints. The variety of fluor called chlorophane emits, as its name expresses, a green light. The same particle may emit varying tints, as in the fluor from Aberdeenshire, which, as the heat falls, or the energy of the phosphorescence wanes, emits tints which pass from violet, through blue, green, and yellow, to dull purplish red. The yellow blende from the same place is vividly phosphorescent when heated. Fluor generally phosphoresces with a tint of its own colour.

Too high a heat destroys the phosphorescence, which may, however, be restored by either exposure to sun's light or to electricity.

The mineral phosphoresces vividly when the discharge passes through it; it generally phosphoresces with a different colour after it has been thus recharged.

Fluorescence. *Fluorescence* is the property whereby rays of light of a refrangibility higher than those ordinarily seen by the human eye are rendered visible. The substance when placed in the violet end of the spectrum, and carried beyond it into the invisible rays, becomes luminous, through "degrading" the rays of extreme refrangibility. This property is well marked in those varieties of fluorite which are pale green by transmitted light, and deep purple by reflected light. Ozocerite and some petroleums also exhibit the property.

Electric, Magnetic, and Thermic Properties.

Electric properties of minerals. *Electricity.*—Friction, pressure, and heat may all excite electricity in minerals. To observe this property delicate electroscopes are required, formed of a light needle terminating at both ends in small balls, and suspended horizontally on a steel pivot by an agate cup. Such an instrument can be electrified negatively by touching it with a stick of sealing-wax excited by rubbing, or positively by merely bringing the wax so near as to attract the needle. When the instrument is in this state, the mineral, if also rendered electric by heat or friction, will attract or repel the needle according as it has acquired electricity of an opposite or of a similar kind; but if the mineral is not electric it will attract the needle in both conditions alike.

Most precious stones become electric from friction, and are either positive or negative according as their surface is smooth or rough. All gems become positive when polished; the diamond even when unpolished is positive. Pressure between the fingers will excite distinct positive electricity in pieces of transparent double-refracting calc-spar. Topaz, aragonite, fluor-spar, carbonate of lead, quartz, and other minerals show this property, but in a much smaller degree. Some bodies remain excited much longer than others, topaz for a very long time. Heat or change of temperature excites electricity in many crystals; as in tourmaline, calamine, topaz, calc-spar, beryl, barytes, fluor-spar, diamond, garnet, and others; these are hence said to be thermo- or pyro-electric. Some acquire polar pyro-electricity, or the two electricities appear in opposite parts of the crystal, which are named its electric poles. Each pole is alternately positive and negative, the one when the mineral is heating, the other when it is cooling. Hankel's investigations of these phenomena are specially noteworthy.

As already noticed, many polar electric minerals are also remarkable for their hemimorphic crystal forms. Tourmaline, calamine, and boracite are among the species thus affected. The polarity continues so long as the temperature is increasing, and becomes reversed when it commences to decline; and when the heat is stationary it disappears.

Pyro-electricity. Rose and Reiss name one of the poles the analogue electric pole, and the other the antilogue electric pole. The former becomes positive while the crystal is heating, and negative while cooling; the latter negative while heating, and positive while cooling. Becquerel found that in tourmaline at 30° C. electrical polarity was sensible; it continued unchanged to 150°, as long as the temperature continued to rise; if the temperature remained

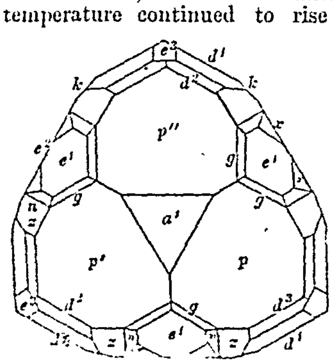


Fig. 249.

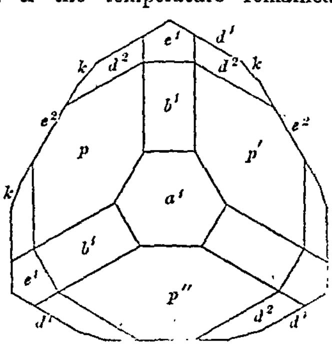


Fig. 250.

stationary an instant, the polarity disappeared, but shortly manifested itself reversed, when the temperature commenced to decline. If but one end of the crystal was heated the crystal was unpolarized, and when two sides were unequally heated each acquired an electrical state independent of the other. In tourmaline the extremities of the prism are dissimilarly modified, and that end which presents the greater number of planes is the antilogue pole; or, if the number of planes is the same, the secondary rhombohedrons of the antilogue pole have (one or more of them) longer vertical axes than those of the analogue pole. Fig. 249 (tourmaline) is the antilogue pole (negative under increasing heat), and fig. 250 the analogue pole. The pyramid of the analogue end is more flattened by its facets than that of the antilogue end; thus e^3 and $d^{\frac{2}{3}}$ of the antilogue end are more acuminating than e^1 and d^2 of the analogue end. The same is the case with the other two crystals (figs. 251, 252).

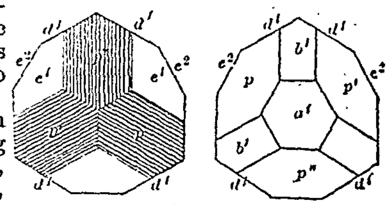


Fig. 251.

Pyro-electricity has been observed in the following substances: — tourmaline, topaz, axinite, boracite, scolezite, prehnite, electric calamine, sphene, rhodizite, heavy spar, rock-crystal.

Pyro-electricity is of two kinds,—either terminally polar or centrally polar. In the former the extremities are opposite poles. In the latter two sides of a prism are of the same name, and the opposite pole to each is intermediate between the two.

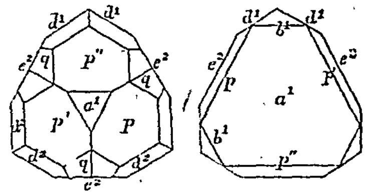


Fig. 252.

The examples of the first kind are tourmaline, calamine, and scolezite, which are uniaxal; axinite, binaxal; boracite and rhodizite, with four axes. Calamine, like tourmaline, has the sharper extremity the antilogue end, and the more flattened the analogue. Compound crystals from Altenberg have both ends analogue, and the portion which lies between the twins antilogue electric; the pyro-electric axis corresponds with the vertical axis of the prism, as in tourmaline. Boracite, which crystallizes in cubic forms, with the opposite solid angles differently modified, has four pyro-electric axes, corresponding to the four octahedral axes. In fig. 253 of this species, the plane which has its angles modified by v is the antilogue pole, and that with the unmodified angles the analogue pole; and, generally, the antilogue pole has either more numerous or larger facets. Rhodizite resembles boracite in its pyro-electricity.

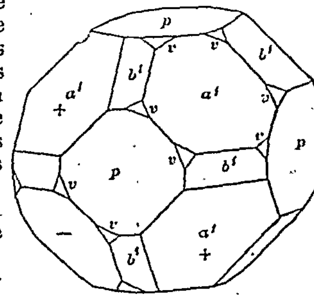


Fig. 253.

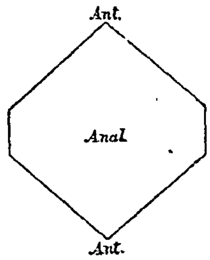


Fig. 254.

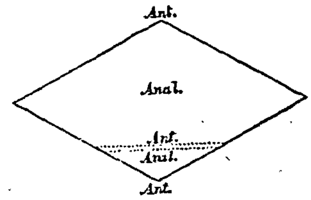


Fig. 255.

The species in which pyro-electricity of the second kind has been observed are prehnite and topaz. If fig. 254 represent a tabular crystal of prehnite, the poles will be situated as marked, the analogue being central, and the antilogue at either extremity of the shorter diagonal of the rhombic prism. Topaz has in a similar manner a central analogue pole, and an antilogue at either extremity of the shorter diagonal. In some instances there is a separate set of similar poles near one or the other angle, as in fig. 255; this must be due to the crystals being of a composite nature.

Magnetism. *Magnetism.*—This property is very characteristic of the few minerals in which it occurs,—chiefly ores of iron or nickel. Some magnetic iron ores possess polar magnetism, or are natural magnets; while the common varieties of magnetite, meteoric iron, magnetic pyrites, precious garnet, and other minerals, are simply magnetic. Most minerals are only attracted by the magnet, but do not themselves attract iron.

Minerals, as other substances, have also been divided into magnetic and diamagnetic. See MAGNETISM.

The ordinary mode of testing whether a mineral is magnetic or not is to bring it near a pole of a delicately suspended magnetic

needle, and observe whether it causes it to vibrate. Another mode is to apply a strong magnet to the mineral in powder. These are sufficient for the mineralogist. Delesse has experimented extensively upon the magnetic force of minerals, and has determined the relative amount for numerous species. Calling this force for Styrian steel 100, the following are some of his results:—

Native platinum	2·173 to 3·047
Magnetic iron ore	15·00 to 65·00
Franklinite, from the United States	1·033
Chromic iron	0·136 to 0·065
Spinel (pleonaste), from Monzoni, Tyrol	0·078
Titanic iron (rhombohedral), often magnetipolar	5·764
Specular iron, sometimes magnetipolar	0·14 to 2·35
Graphite	0·015 to 0·040
Spathic iron (spherosiderite, the highest)	0·092 to 0·287
Iron pyrites	0·039 to 0·057
Vivianite	0·027 to 0·075
Columbite of Bodenmais and Haddam	0·151
Pyrochlore	0·010
Chrysoprase (quartz is diamagnetic, but many varieties are magnetic)	0·004
Felspar, sometimes feebly magnetic.	
Labradorite of an antique green porphyry	0·077
Hornblende	0·012 to 0·057

Magnetic polarity.

Crystallomagnetic Action.—The magnetic polarity thus far alluded to belongs to the mass, and has no relation to crystalline form. There is also a kind of polarity directly related to the crystalline or optic axes of minerals. A crystal of cyanite, suspended horizontally, points to the north, by the magnetic power of the earth only, and is a true compass needle, from which even the declination may be obtained; and the line of direction is the line of the optic axes. Other crystals, which are called negative, take a transverse or equatorial position. The latter are diamagnetic crystals.

Heat conductivity.

Conductivity for Heat.—Senarmont found that the conducting power of colloids and of crystals of the cubic system is equal in all directions, but that it varies in different directions in crystals belonging to all the other systems, exhibiting characters analogous to those deduced from their double refraction, conformable with the optic axes of the crystal, and referable, as in the latter case, to axes of elasticity, or unequal compression of the molecules.

The fundamental fact is easily shown by taking two slices of rock-crystal, one cut transverse to the axis and one parallel to it. Through the centre of each plate a small hole is drilled for the reception of a bent wire, which by insertion into the hole sustains the plate. The other end of the wire is to be heated, and the rate of the conduction of the heat is rendered visible by the amount of a thin coating of beeswax, with which the plate has been previously coated, which is melted round the central hole. It will be seen that in the transverse slice the wax is melted in a circular form, while in the longitudinal slice the form is elliptical (fig. 256). The conduction is equal in all directions, as regards the transverse axes of the hexagonal prism, but more rapid in one direction in the longitudinal slice, and that direction is the line of its optic axis. In the case of quartz the two diameters of the ellipse are as 1000 to 1312.

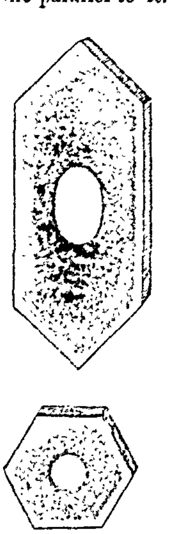


Fig. 256.

If the regular disposition of the molecules of amorphous bodies be interfered with by unequal tension or compression, the regularity of their power of conducting heat is destroyed, and they also show elliptical forms of melted wax; and the shorter axis of the ellipse is in the line of pressure or undue packing of the molecules. The heat thus does not travel so fast in this direction,—partly because it is spent in the heating up of the greater number of molecules. Hence we might conclude that along the main axis of quartz a smaller number of molecules are packed in an equal space than along the transverse. The following are the more important of Senarmont's results.

Senarmont's investigations.

1. Crystals of the tetragonal and rhombohedral systems have one axis of conductivity which is either greater or smaller than the others, and this axis coincides with the main crystallographic axis. The isothermal surfaces are ellipses which lie in the line of this axis, and these ellipses may be either elongated or flattened in the direction of this line.

2. In crystals of the right prismatic system the isothermal surfaces have three unequal axes, which coincide with crystallographic axes drawn parallel to the edges of the rectangular prism.

3. In crystals of the oblique rhombic system the isothermal surfaces have three unequal axes, one of which coincides with the horizontal diagonal of the base, while the other two have directions which are not referable to any law.

4. In crystals of the anorthic system the isothermal surfaces have three unequal axes, all with indeterminable positions.

In crystals of a single axis there appears to exist no constant relation between the axis of optic elasticity, whether maximum or minimum, and the axis of the greatest or of the least calorific conductibility. Thus, of the minerals examined by Senarmont, quartz (+), calcite (−), cassiterite (+), rutile (+), and calomel (+) have all their greatest axis of conductibility parallel to the principal axis; idocrase, beryl, tourmaline, and corundum, all optically negative, have on the contrary their smallest axis of conductibility parallel to the axis.

In crystals belonging to the oblique rhombic system there is rarely coincidence between the thermic axes and the axes of optic elasticity. In gypsum and in felspar these lie apart to a marked extent.

Dilatation.

Dilatation by Heat.—In crystals of those systems in which the molecules are arranged unequally as regards their axes, the amount of their dilatation when heated is unequal in the direction of their axes. Our knowledge of this subject is chiefly due to Mitscherlich.

In crystals of cubic symmetry the expansion is equal in all directions. The dimetric systems—the pyramidal and hexagonal—are brought together as regards this quality, inasmuch as the axes of volumetric change are in these the same; for, while these in the pyramidal correspond with the crystallographic axes, in the hexagonal the three axes are the vertical, one lateral axis, and an axis lying intermediate to the other two and at right angles to the first lateral axis. The expansion along the principal axis may be either greater or less than along the others; and in some minerals there is even contraction along one axis.

In the right prismatic system the axes of dilatation correspond to those of form. In the oblique prismatic one axis corresponds with the orthodiagonal, but the others make angles not only with the other crystallographic axes but, strange to say, with the axes both of thermic conductivity and of optic elasticity. We are as yet ignorant of the properties of anorthic crystals in this respect.

As a consequence of this unequal expansion along different axes, the angles of crystals, other than those of the cubic system, are altered under the influence of heat. The alteration is extreme in the case of calcite, where, through elongation along the vertical axis, with some concomitant contraction of the transverse, the angle of the rhombohedric faces is, when the crystal is heated from 32° to 212° F., diminished from 105° 5′ to 104° 56′ 23″,—the form thus approaching that of a cube, as the temperature is raised.

Dolomite, in the same range of temperature, diminishes 4′ 46″. In some rhombohedrons, as of calc-spar, the vertical axis is lengthened (and the lateral shortened), while in others, like quartz, the reverse is true. The variation is such, either way, that the double refraction is diminished with the increase of heat; for calc-spar possesses negative double refraction, and quartz positive. According to Fresnel the same is true of gypsum. The dilatation for calc-spar, according to experiment, is 0·001961.

Kopp has shown that in the carbonates of lime, magnesia, iron, manganese, and zinc, which are nearly the same in the angle of their crystals, the vertical axis is shorter the greater the atomic volume And since heat diminishes the density, and therefore necessarily increases the volume, the axis a should be lengthened by an increase of temperature, as is actually the case. He has determined by calculation that the change of angle from 32° to 212° should be 7′ 37″.

Although in the greater number of cases the variations are so small as to be scarcely measurable, yet they may be sufficient for establishing a difference between substances which have identical geometric form while belonging to different systems of crystallization. The angle of a rhombohedron might at a certain temperature be 90°, and so coincide with a cube; but that angle would in a rhombohedron change whenever the temperature altered, while the angle of a true monometric cube is constant at all temperatures. The increase in volume and diminution in density which generally result from heating are always accompanied by a change in optical properties. In trimetric crystals, where the principal indices alter unequally, the change affects the amount of divergence of the optic axes. The amount of alteration in gypsum, when the divergence is diminished, is extreme. At the ordinary temperature the angle of the divergence of the optic axes which lie in the plane of symmetry is about 90° for red light; when heated to 177° it is diminished to 0°, and for the moment the crystal appears to be uniaxal. When more highly heated, the axes again diverge, but in a plane at right angles to the original one, and in cooling these changes take place in reverse order. In barytes and celestine again, the alteration in the angle of the optic axes is a divergence when heated.

Characters depending on Cohesion.

These characters are of five kinds:—(1) hardness, (2) tenacity, (3) elasticity, (4) cleavage, (5) fracture. All may be considered as related to the power of resisting attempts to separate one part from another.

Hardness.

1. *Hardness.*—A harder body is distinguished from a softer, either by attempting to scratch the one with the other, or by trying each with a file. Each of these methods is used by the mineralogist in determining the hardness of the species, though the latter is in most cases to be preferred. Both methods should be employed when practicable.

Certain varieties of some minerals give a low hardness under the file, owing either to impurities or imperfect aggregation of the particles, while they scratch another mineral upon which a file would have no effect, showing that the particles of the first are hard, though loosely aggregated. Chiastolite, spinel, and sapphire are common examples of this. When the mineral is too hard to be impressed by a file, the peculiarity of the grating sound will suffice for the practised ear.

Mohs introduced a scale of hardness, consisting of ten minerals, which gradually increase in hardness from 1 to 10. The intervals between 2 and 3 and 5 and 6 are larger than the others. Breithaupt has therefore introduced another degree of hardness between each of the above, and thus his scale consists of twelve minerals.

The scale is as follows:—

1. Talc, common laminated light green variety.
2. Gypsum, a crystallized variety.

2·5. Mica (muscovite).

3. Calcite, transparent variety.
4. Fluor-spar, crystalline variety.
5. Apatite, transparent variety.

5·5. Scapolite, crystalline variety.

6. Felspar (orthoclase), white cleavable variety.
7. Quartz, transparent.
8. Topaz, transparent.
9. Sapphire, cleavable varieties.
10. Diamond.

If the file abrades the mineral under trial with the same ease as No. 4, and produces an equal depth of abrasion with the same force, its hardness is said to be 4; if with more facility than 4 but less than 5, the hardness may be $4\frac{1}{4}$ or $4\frac{1}{2}$, written in decimals 4·25, 4·5. Several successive trials should be made to obtain certain results.

The use of the file is acquired with very little experience; usually a single trial is sufficient. Care must be taken to apply the file to edges of equal obtuseness. That part also of the specimen should be selected which has not been altered by exposure, and has the highest degree of transparency and compactness of structure. The pressure for determination should be rather heavy, and the file should be passed three or four times over the specimen.

Where the scale of hardness is wanting, or a first rough determination is sought, the following experiments may serve:—

Every mineral that is scratched by the finger-nail has H. = 2·5 or less. Minerals that scratch copper have H. = 3 or more. Polished white iron has H. = 4·5. Window-glass has H. = 5 to 5·5. Steel point or file has H. = 6 to 7; hence every mineral that will cut or scratch with a good penknife has H. less than 6. Flint has H. = 7, and only about a dozen minerals, including the precious stones or gems, are harder.

Many specimens present different degrees of hardness on dissimilar faces; as an example of which we mention cyanite and mica. This is confined to the inequilateral primary forms, and like the similar difference of colour, lustre, &c., finds a ready explanation in the theory of their formation; unlike faces are the result of the action of a polar force acting along unlike axes.

This difference in faces parallel to unlike axes may be perceived in nearly all cases, when the methods of trial are sufficiently delicate. Huygens observed long ago that the cleavage face of a crystal of calc-spar differed in hardness from the other faces; and even in a monometric crystal it has been found that the faces of the cube and octahedron are not exactly alike in this respect.

Tenacity.

2. *Tenacity.*—Solid minerals are said to be brittle, sectile, malleable, flexible, or elastic:—

1. *Brittle,* when parts of a mineral separate in powder or grains on attempting to cut it; as baryte, calc-spar.
2. *Sectile,* when pieces may be cut off with a knife without falling to powder, but still the mineral pulverizes under a hammer; as brucite, gypsum.
3. *Malleable,* when slices may be cut off, and these slices flatten out under a hammer; as native gold, native copper.
4. *Flexible,* when the mineral will bend and remain bent after the bending force is removed; as gypsum, graphite, talc.
5. *Elastic,* when after being bent it will spring back to its original position; as mica.

A liquid is said to be *viscous* when, on pouring it, the drops lengthen and appear ropy; as petroleum.

Elasticity.

3. *Elasticity.*—Investigations on this property have not to any extent been entered upon. The unequal elasticity of unlike faces of crystals has been shown by Savart in his acoustic investigations, and he was able to distinguish the rhombohedral from the other faces in the pyramid of quartz crystals; he also showed that the figures formed upon vibrating plates of crystals were directly connected with their optic axes. Milne, by measuring the amount of recoil of a sphere of calcite when struck at different points by another of rock-crystal, found that the elasticity, as thus measured, was greatest along the line of the optic axis, and least in directions at right angles to it. He also found that points which lay intermediate between the main and the transverse axes were most indented by the blows. This goes to show that, although there may be fewest molecules arranged along the lines of the transverse axes, yet cohesion operates with greater intensity along these than in intermediate directions.

When the tenacity of a mineral is overcome by an overwhelming amount of traction, or its elasticity by a sudden shock, its parts are separated, either in flat and continuous surfaces, or in surfaces which are irregular in the extreme. The first of these modes is termed cleavage, the second fracture. In those substances in which cleavage exists it is found that the planes or directions along which it takes place lie in certain strictly definite positions to one another and to the axes of the crystal. They show not the smallest tendency to a transition or gradual passage into the other directions of greater coherence.

Cleavage.

4. *Cleavage.*—The number of these parallel cleavage-planes is altogether indefinite, so that the only limit that can be assigned to the divisibility of some minerals, as gypsum and mica, arises from the coarseness of our instruments. These minima of coherence, or cleavage-planes, are always parallel to some face of the crystal; and similar equal minima occur parallel to every other face of the same form. Hence they are always equal in number to the faces of the form, and the figures produced by cleavage agree in every point with true crystals, except that they are artificial. They are thus most simply and conveniently described by the same terms and signs as the faces of crystals.

Some minerals cleave in several directions parallel to the faces of different forms, but the cleavage is generally more easily obtained and more perfect in one direction than in the others. This complex cleavage is well seen in calc-spar and fluor-spar, and very remarkably in zinc blende, where it takes place in no less than six directions. As in each of these the division may be indefinitely continued, it is clear that no lamellar structure in any proper sense can be assigned to the mineral. All that can be affirmed is that contiguous atoms have less coherence along a direction normal to these planes than in other directions. When cleavage takes place in three directions, it of course produces a perfect crystal form, from which the system of crystallization and angular dimensions of the species may be determined; it is thus often of very great importance.

The common cleavage in the different systems is as follows, those of most frequent occurrence being in italics:—(1) In the cubic system, *Octahedral,* O, along the faces of the octahedron; *Hexahedral,* $\infty O \infty$, along those of the cube; and Dodecahedral, ∞O. (2) In the tetragonal system, Pyramidal, P, or $2P\infty$; *Prismatic,* ∞P, or $\infty P \infty$; or *Basal,* 0P. (3) In the hexagonal system with holohedral forms, Pyramidal, P, or P2; *Prismatic,* ∞P, or $\infty P \infty$; or *Basal,* 0P; with rhombohedral forms, *Rhombohedral,* R; Prismatic, ∞R; or *Basal,* 0R. (4) In the right prismatic system, Pyramidal, P; *Prismatic,* ∞P; Macrodomatic or Brachydomatic, $\bar{P}\infty$ or $\breve{P}\infty$; *Basal,* 0P; Macrodiagonal, $\infty \bar{P} \infty$; or *Brachydiagonal,* $\infty \breve{P} \infty$. (5) In the oblique prismatic system, Hemipyramidal, P, or $-P$; *Prismatic,* ∞P; Clinodomatic, $P^{c}\infty$; Hemidomatic, $P^{o}\infty$ or $-P^{o}\infty$; *Basal,* 0P; Orthodiagonal, $\infty P^{o} \infty$; or *Clinodiagonal,* $\infty P^{c} \infty$. (6) In the

anorthic system, Hemiprismatic, $\infty P'$, or ∞P; Hemidomatic either along the macrodome or the brachydome: *Basal*, $0P$; Macrodiagonal, $\infty \bar{P} \infty$; or *Brachydiagonal*, $\infty \breve{P} \infty$.

In some minerals, as mica and gypsum, the cleavage is readily procured; these may be held in the hand and divided by a knife. Others only cleave with more or less difficulty; these must be placed on a firm support resting on lead, folded paper, or cloth, and a sharp blow struck on a chisel applied in a proper direction. This may often be ascertained by examining the specimen in a strong light. Sometimes it is necessary to subject them to extreme compression in a vice. Some of the hardest substances have not only a perfect but a facile cleavage,—as euclase, topaz, and diamond; many of the softest species have none. The planes produced also vary much in their degree of perfection, being highly perfect in some, as mica and calc-spar, and imperfect in others, as garnet and quartz. In a very few crystalline minerals cleavage-planes can hardly be said to exist. Cleavage must be carefully distinguished from the planes of union in twin crystals, and the division-planes of laminar minerals.

racture. 5. *Fracture.*—This is the irregular manner in which substances may be broken. Even minerals possessed of cleavage may be fractured in other directions; but in amorphous bodies fracture alone occurs. The following varieties of fracture occur, and are highly characteristic:—

1. *Conchoidal*, almost typical of amorphous bodies, but occassionally seen in crystals,—rounded cavities, more or less deep. The name is taken from the resemblance to the successive lines of interrupted growth in a bivalve shell. Seen in flint, obsidian, asphalt. In calcite the direction of this fracture is intermediate to the planes of the mineral's cleavage.
2. *Even*, when the surface of fracture is smooth and free from inequalities.
3. *Rough*, when the surface of fracture is rugged, with numerous small elevations and depressions.
4. *Splintery*, when covered with small wedge-shaped splinters.
5. *Hackly*, when the elevations are sharp, slightly bent, or jagged, as broken iron.
6. *Earthy*, when it shows only fine dust.

Taste, Odour, Touch.

aste. *Taste* belongs only to soluble minerals. The different kinds adopted for reference are as follows:—

1. *Astringent*, the taste of blue vitriol.
2. *Sweetish astringent*, taste of alum.
3. *Saline*, taste of common salt.
4. *Alkaline*, taste of soda.
5. *Cooling*, taste of saltpetre.
6. *Bitter*, taste of epsom salts.
7. *Sour*, taste of sulphuric acid.
8. *Pungent*, taste of sal-ammoniac.
9. *Metallic*, taste of zinc sulphate.

dour. *Odour.*—Excepting a few gaseous and soluble species, minerals in the dry unchanged state do not give off odour. By friction, moistening with the breath, and the elimination of some volatile ingredient by heat or acids, odours are sometimes obtained which are thus designated:—

1. *Alliaceous*, the odour of garlic. Friction of arsenical iron elicits this odour; it may also be obtained from any of the arsenical ores or salts by means of heat.
2. *Horse-radish odour*, the odour of decaying horse-radish. This odour is strongly perceived when the ores of selenium are heated.
3. *Sulphurous*. Friction will elicit this odour from pyrites, and heat from many sulphurets.
4. *Bituminous*, the odour of bitumen.
5. *Fetid*, the odour of sulphuretted hydrogen or rotten eggs. It is elicited by friction from some varieties of quartz and limestone.
6. *Argillaceous*, the odour of moistened clay. It is obtained from serpentine and some allied minerals after moistening them with the breath; others, as pyrargillite, afford it when heated.
7. *Empyreumatic* or *ozonic*. Quartz, when two portions strike one another.

ich. *Touch.*—Some minerals are distinguished by a greasy feeling, as talc; others feel smooth, as celedonite; others meagre, like clay; others cold. This last character distinguishes true gems from their imitations in glass. Some, in virtue of their hygroscopic nature, adhere to the tongue.

Chemical Properties of Minerals.

Influence of Chemical Composition on the External Characters of Minerals.—That the characters of a compound must to a certain extent depend on those of its component elements seems, as a general proposition, to admit of no doubt. Hence it might be supposed possible from a knowledge of the composition of a mineral to draw conclusions in reference to its form and its other properties; but practically this has not yet been effected. Relation of composition to physical properties.

The distinction between the mineralizing and mineralizable or the forming and formed elements lies at the foundation of all such inquiries. Certain elements in a compound apparently exert more than an equal share of influence in determining its physical properties. Thus the more important non-metallic elements, as oxygen, sulphur, chlorine, fluorine, are remarkable for the influence they exert on the character of the compound. The sulphurets, for example, have more similarity among themselves than the various compounds of one and the same metal with the non-metallic bodies. Still more generally it would appear that the electro-negative element in the compound is the most influential, or exerts the greatest degree of active forming power. After the non-metallic elements the brittle, easily fusible metals rank next in power; then the ductile ignoble metals; then the noble metals; then the brittle, difficultly fusible; and, last of all, the metals of the earths and alkalies.

Generally each chemical substance crystallizes only in one form or series of forms. Some substances, however, show dimorphism, or crystallize in two forms, and thus may compose two or more minerals. Thus sulphur, which in nature usually crystallizes in the right prismatic system, when melted forms oblique prismatic crystals. Carbon in one form is the diamond, in another graphite; carbonate of lime appears as calc-spar and as aragonite; the bisulphuret of iron as pyrite and as marcasite. An example of trimorphism occurs in titanic acid, forming the three distinct species anatase, rutile, and brookite. It is remarkable that of dimorphic minerals one form is almost always right prismatic; thus:—

	Rhombic Form.
Cyanite, anorthic	Sillimanite, Andalusite.
Calc-spar, hexagonal	Aragonite.
Susannite, *do.*	Leadhillite.
Rutile, Anatase } pyramidal	Brookite.
Pyrolusite, right prismatic	Polianite.
Cuprite, cubic	Chalcotrichite (?)
Senarmontite, cubic	Valentinite.
Pyrite, do.	Marcasite.
Rammelsbergite, do	Chloanthite.
Argentite, do	Acanthite.
Freieslebenite, oblique prismatic	Diaphorite.
Sulphur, do.	Sulphur.

Even the temperature at which a substance crystallizes influences its forms, and so far its composition, as seen in aragonite, Glauber salt, natron, and borax.

Isomorphism.—Still more important is the doctrine of isomorphism, designating the fact that two or more simple or compound substances crystallize in one and the same form, or often in forms which, though not identical, yet approximate very closely. This similarity of form is generally combined with a similarity in other physical and in chemical properties. Among minerals that crystallize in the tesseral system, isomorphism is of course common and perfect, there being no diversity in the dimensions of the primary form; but for this very reason it is generally of less interest. It is of more importance among crystals of the other systems, the various series of which are separated from each other by differences in the proportions of the primary form. In these perfect identity is seldom observed, but only very great similarity. Isomorphism.

The more important isomorphic substances are either simple substances, as (1) fluorine and chlorine; (2) sulphur and selenium; (3) arsenic, antimony; (4) cobalt, iron, nickel; (5) copper, silver, mercury, gold (?); or combinations with oxygen, as (6) lime, magnesia, and the protoxides of iron, manganese, zinc; (7) sesquioxides, as of iron, manganese, chromium, and alumina; (8) phosphoric acid, vanadic acid, arsenic acid; (9) sulphuric, selenic, chromic acids; or combinations with sulphur, as (10) sulphuret of iron and of zinc; (11) sulphuret of antimony and of arsenic; (12) sulphuret of lead, of copper, and of silver. These substances are named vicarious from the singular property that in chemical compounds they can mutually replace each other in definite proportions, and very often without producing any important change in the form or other physical properties. But there are numerous instances among the silicates where the mutual replacement of the isomorphic

bodies, especially when the oxides of the heavy metals come in the room of the earths and alkalies, exerts a most essential influence on the external aspect of the species, particularly in regard to colour, specific gravity, and transparency. The varieties of hornblende, augite, garnet, epidote, and many other minerals are remarkable proofs of this influence. This intermixture of isomorphic elements confers many valuable properties on minerals, and to it this department of nature owes much of its variety and beauty. Without the occasional presence of the colouring substances, especially the oxides of iron and manganese, the non-metallic combinations would have exhibited a very monotonous aspect. It is also remarkable that in some silicates the substitution of a certain portion of the metallic oxides for the earthy bases seems to be almost a regular occurrence; whilst in others, as the felspars and zeolites, this rarely happens. This fact is also of great economic interest, as drawing attention to important elements often combined with others of less value. Thus iron oxide and chrome oxide, sulphuret of copper and sulphuret of silver, nickel and cobalt, may be looked for in connexion. The general chemical formulæ for such compounds is formed by writing R (=radical or basis) for the whole isomorphic elements; and in special instances their signs are placed one below the other, connected by a bracket, or, as is more convenient, are enclosed in brackets one after the other separated by a comma. Thus the general sign for the garnet is $\dot{R}_3\ddot{Si}_2+\dddot{R}\ddot{Si}$, which, when fully expressed, becomes $(\dot{Ca}_3, \dot{Fe}_3, \dot{Mg}_3, \dot{Mn}_3)\ddot{Si}_2+(\dddot{Al}, \dddot{Fe}, \dddot{Cr})\ddot{Si}$; and this mineral forms many varieties as the one or other element preponderates.

Of the forms special to similar groups of atoms the more notable are—the cubic system, special to metals proper, and binary compounds as protoxides and haloid salts; the tetragonal to binoxides; the rhombohedral to carbonates; the hexagonal to sesquioxides and phosphates and their isomorphs; the prismatic to sulphates and their isomorphs.

The isomorphism of minerals goes as a whole to show that form depends on the number of molecules present, and is comparatively little influenced by the nature of the molecules themselves.

DESCRIPTION OF MINERAL SPECIES.

The arrangement adopted in the following description of mineral species is chemical. Simple substances are considered first, in the order of their quantivalence, then binary compounds, and lastly those of more complex structure. Our limits permit of the briefest notice of the less important, in order that more space may be available for the delineation of the characteristic and transition forms of such as go to constitute the more important rock masses.

The following abbreviations are used:—H., hardness; G., specific gravity (distilled water at 60° Fahr. and barometer 30 inches=1); cl., cleavage; sol., soluble; s. [h. or n.] acid, sulphuric [hydrochloric or nitric] acid; B.B., before blowpipe; ox., oxidizing; red., reducing; c.c., chemical composition; com., combination.

In the chemical formulæ, barred letters express two equivalents, and the dots over the symbols indicate the combination with them of as many equivalents of oxygen as there are dots.

In the symbolic notation the several faces of crystals are separated by semicolons, and the constituent members of combinations by commas. The lettering on the faces of the figures is for the most part that adopted by Miller. In the enumeration of crystal forms, that which is typical of the mineral is placed first.

SIMPLE SUBSTANCES.

Bi-valent elements.

1. SULPHUR, S.

(*a*) Right prismatic. P (*p*) polar edges 106° 38′, 84° 58′, middle edge 143° 17′; ∞P 101° 58′; 0P (*c*); $\frac{1}{3}$P (*s*); P̆∞ (*n*). Crystals pyramidal, single or in druses; also stalactitic, disseminated, and pulverulent. Cl. basal and ∞P. H.=1·5 to 2·5; G.=1·9 to 2·1. Fracture conchoidal or splintery; brittle, sectile. Lustre resinous, streak and colour sulphur-yellow, passing into red, brown, or green. Sublimes in the closed tube. Fuses a little above the temperature of boiling water. Takes fire at 518° F., and burns with a pale blue flame with odour of sulphurous acid. C.c.: pure sulphur, occasionally mixed with traces of selenium, and when amorphous with clay or bitumen. Found chiefly in Tertiary strata. Localities: Girgenti in Sicily, with celestine; Conil in Spain; Bex in Switzerland; Cracow in Poland; deposited from hot springs in Solfatara near Naples; from hot springs in Iceland; from sulphur springs in New York; and in cavities of decomposing galena, cinnabar, and pyrites at several localities.

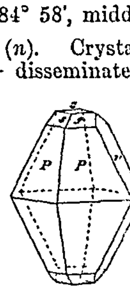


Fig. 257.

(*b*) Oblique prismatic. The crystals of volcanic sulphur are of this form; they occur in the neighbourhood both of extinct and of recent volcanoes. They are slender, needle-shaped, and interlacing, and have generally more or less of a red-brown tinge. Oxhaveer and Cape Reykjanes in Iceland, Sicily, and the volcanoes of the Pacific, the Chilian Andes, and California yield this variety.

2. SELENSULPHUR, S.Se.

Like sulphur, but reddish brown to orange-yellow. B.B. burns with fumes of selenious acid mixed with the sulphurous. Found in the crater of Volcano in the Lipari Islands, and Kilauea in Hawaii.

3. SELENIUM, Se.

H.=2; G.=4·3. Brownish black to lead-grey; thin splinters translucent and red. From Culebras in Mexico.

4. TELLURIUM, Te.

Rhombohedral; R 86° 50′. In minute hexagonal prisms, with basal edges replaced; usually massive and granular. Cl. lateral perfect, basal imperfect. H.=2 to 2·5; G.=6·1 to 6·3. Tin-white; sectile. C.c.: tellurium with a little gold and iron. Occurs at Facsebaya near Zalathna (Transylvania), and in several mines in Boulder county, Colorado; masses 25 lb in weight have been obtained there.

5. ARSENIC, As.

Tri-valent elements.

Rhombohedral; R 85° 36′ (fig. 258). Usually in botryoidal investing masses composed of numberless layers. The structure is fine granular, rarely columnar. H.=3·5; G.=5·7 to 5·93. Cl. basal. Colour black and dull, but when fresh broken very splendent and silver-white; fracture uneven. When rubbed or heated gives out a garlic-like odour. B.B. volatile, with formation of white fumes. C.c.: arsenic, with some antimony, and traces of iron, silver, and gold. Andreasberg in the Harz, Annaberg, Schneeberg, Freiberg, Joachimsthal, Allemont (Dauphiné), Kongsberg (Norway), the Altai, Chili, Pebble mine (Dumfriesshire), Tyndrum (Perthshire).

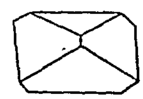


Fig. 258.

6. ANTIMONY, Sb.

Rhombohedral; R 87° 35′; but rarely crystallized, generally in foliated or granular masses. Cl. basal. H.=3; G.=6·6 to 6·8. Tin-white, with slight yellow tarnish. Brittle and sectile. B.B. easily fusible; volatilizes, and on charcoal leaves a white deposit, burning with a pale flame. Found at Andreasberg, Przibram (Bohemia), Sala (Sweden), Allemont, Southham in East Canada, and Borneo.

7. ALLEMONTITE, $SbAs_3$.

Hexagonal, spherical, reniform, and investing. H.=3·5; G.=6·1 to 6·2. Lustre, when fresh, metallic. Tin-white to lead-grey, but with a blue or brown tarnish. B.B. strong odour of garlic, with residuum of oxide of antimony. C.c.: antimony 37·85, arsenic 62·15. Almost always in curved foliated laminæ. Occurs at Allemont, Przibram, Schladming in Styria, Andreasberg.

8. BISMUTH, Bi.

Rhombohedral; R 87° 40′. Crystals, -R, 0R, generally distorted; also reticulated, spear-head twins, or arborescent; also disseminated and granular. Cl. basal, perfect. H.=2·5; G.=9·6 to 9·8. Brittle and sectile. Reddish white, often tarnished grey, brown, or blue. B.B. easily fusible, even in candle flame. Volatilizes on charcoal, leaving a citron-yellow crust. Sol. in n. acid; solution precipitated when thrown into water. Occurs in gneiss and clay slate in veins and disseminated, along with ores of cobalt, silver, lead, and zinc. Alva in Stirlingshire, Cumberland, Devonshire and Cornwall, Schneeberg, Marienberg, Joachimsthal, Bieber, Modum (Norway), Falun (Sweden), Bolivia.

9. TELLURIC BISMUTH, Bi_2Te_3.

Bismuth 52, tellurium 48. Virginia, Dahlonega in Georgia, Montana. A variety with 7 per cent. of selenium and H.=2 also occurs.

10. TETRADYMITE, Bi_2Te_2S.

Rhombohedral; 3R 68° 10′. Almost always twins of 3R and 0R, with the faces of 0R at 93°. Cl. basal, perfect. Sectile, and thin laminæ flexible. H.=1 to 2; G.=7·2 to 7·5. Steel-grey. B.B. fuses, yielding a grain of metal which ultimately volatilizes. Sol. in n. acid. C.c.: 59·6 bismuth, 35·9 tellurium, and 4·5 sulphur. Schemnitz.

11. Wehrlite, $Bi(Te_3S)$.

Hexagonal. Cl. basal. H. = 1 to 2; G. = 8·44. High lustre. Steel-grey. C.c.: bismuth 61·15, tellurium 29·74, sulphur 2·33, silver 2·07. Deutsch-Pilsen in Hungary.

12. Joseite, $Bi_3Te_2(SSe)_2$.

Hexagonal. Cl. basal. G. = 7·93. Colour grey-black to steel-grey. Brittle. C.c.: tellurium 15·93, sulphur 3·15, selenium 1·48, bismuth 79·15. San José (Brazil). A Cumberland variety yielded tellurium 6·73, sulphur 6·43, bismuth 84·33, corresponding to $Bi_4(TeS_4)$.

13. Diamond, C.

Quadrivalent elements.

Var. 1. *Crystallized.*—Cubic; very frequently hemihedral. Crystals most generally with curved faces. Twins common on the octahedral face; hemitropes also common (see figs. 170, 204, 205, 207). Crystals vary remarkably in appearance (see figs. 259 to 262). Cl. octahedral. H. = 10; G. = 3·5 to 3·6. Transparent, or translucent when of dark colour. Refracts light strongly. The back planes of diamonds reflect all the light which strikes them at an angle exceeding 24° 13′, and thence comes their peculiar brilliancy. High adamantine lustre. Colourless, but often tinged white, grey, and brown,—more rarely yellow, pink, blue, green, and black, those last named being the rarest. Disperses light highly, and hence emits brilliant flashes of all the colours of the spectrum. Becomes positively electric by friction. B.B. infusible, but burns into carbonic

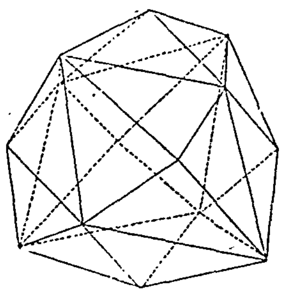


Fig. 259.

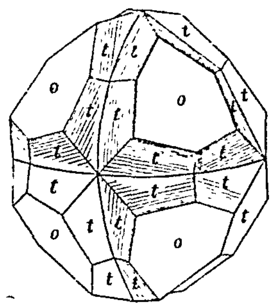


Fig. 260.

acid in oxygen gas. When air is excluded is unchanged at the temperature of melting cast iron, but at that of melting malleable iron is changed into a black coke, or, it is said, into graphite. Insoluble in all acids and alkalies. C.c.: carbon, with traces of silica and earths. Geologic formation apparently a laminated flexible quartz rock called itacolumite, which occurs in Brazil, the Urals, Georgia, and North Carolina, in the vicinity of places where diamonds have been found. Minute crystals have been found in xanthophyllite, and in talc slate and serpentine, in the Schischimskian hills, near Zlatoust (Russia). They have also been obtained in Brazil imbedded in a conglomerate composed of much-worn pebbles of quartz, chalcedony, and gold, cemented by limonite or

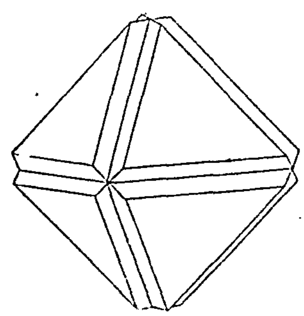


Fig. 261.

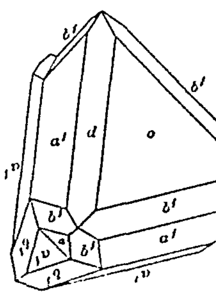


Fig. 262.

ferruginous clay. In South Africa they are imbedded in a steatitic clay. Diamonds were formerly obtained in India, at Panna, Raolconda, and Golconda. So few are now obtained here that the mines are let for £1 a year. From these mines were obtained not only the Kohinoor, which was possibly the same as the great diamond mentioned by Tavernier as having been seen by him in the possession of the Great Mogul, which weighed 280 carats, but the Regent, of 136 carats (which, not only from its size, but from the perfection of its form, is very much the finest diamond known), the Nizam, an uncut diamond of 340 carats, and the Carlow, rose-cut, 193 carats. More lately diamonds were found in great quantity in the neighbourhood of Rio Janeiro in Brazil; they occur in two different deposits: the one called "gurgulho" consists of broken quartz covered by a bed of sand; the other, "cascalho," consists of rolled quartz pebbles united by ferruginous clay; both rest on talcose clays, which are the debris from talcose rocks. The first deposit affords the finest diamonds, and both contain gold, platinum, magnetite, and rutile. A dodecahedral diamond of 257 carats was lately found at Bogagem in this district; this was reduced by cutting to an oblong brilliant of 125 carats, and is the second most valuable diamond,—the Kohinoor, now reduced to an imperfectly circular brilliant of 102 carats, occupying the third place. The two coloured diamonds most worthy of note are a green diamond in the Dresden collection weighing 31 carats, which is a little deeper in tint than a beryl, and a blue diamond in the Hope collection, of 44 carats, as highly coloured as a sapphire, which it is by some considered to be. Diamonds have lately been found in very large quantities, and some of great size, north of the Cape of Good Hope; these for the most part are of yellow colour and of very inferior value. While a Brazilian cut brilliant of one carat is worth from £20 to £25, the value of the finest brilliants from the Cape is only from £3 to £4, and that of the yellow diamonds is from £2 to £2, 10s. Apart from its employment as an ornamental stone, the diamond has an intrinsic value from its being utilized for cutting glass and for grinding and polishing other gems. Of late years its usefulness has had a new application, it being employed for the drilling of rocks in tunnelling operations and in the boring of artesian wells. A singular observation has resulted from these last methods of utilizing it, namely, that the hardness of the African diamonds, as tested by the amount of their endurance, is markedly inferior to that of the Brazilian and Indian. So much is this recognized that, while the bort, or minute crystals, of the latter command a price of 15s. per carat, the African can be got for about 5s. The cleavage of certain of the African diamonds is so eminent that even the heat of the hand causes some of them to fall in pieces. Such diamonds, generally octahedra, may be recognized by a peculiar watery lustre; they are called plate diamonds. The above facts give some ground for the supposition that there may be a slight difference in their composition, possibly that both may contain small, but different, quantities of hydrogen. The circumstances under which diamonds have been formed are altogether unknown. The fact of their being changed into a kind of coke at a very high temperature is an argument against their having been produced through the operation of heat, and it has long been known that an excess of carbon dissolved by molten cast iron crystallizes on cooling in the form of graphite; yet the only attempts to form diamonds deserving of being mentioned as having been attended with any measure of success are those in which sugar charcoal was dissolved in molten silver at the temperature only of melting steel. There were thus obtained a few minute black and also colourless octahedral and cubo-octahedral crystals with curved faces, mingled with a much larger amount of graphitoidal carbon.

Var. 2. *Massive.*—In black pebbles or masses called *carbonado*, sometimes 1000 carats in weight. H. = 10; G. = 3·012 to 3·42. C.c.: carbon except ·27 to 2·07 per cent. of ash. Found in the mines of Baranco, &c., in Bahia.

Var. 3. *Anthracitic.*—Like anthracite, but scratches the diamond. In mammillar masses, partly in concentric layers, and globular. Brittle. G. = 1·66. C.c.: carbon 97, hydrogen ·5, oxygen 1·5. When cut and polished, refracts and disperses light, like the diamond. Supposed from Brazil.

14. Graphite, C.

Hexagonal in flat crystals; $p{:}p$ 85° 29′. Usually foliated, scaly, or compact. Cl. basal. H. = 0·5 to 1; G. = 1·9 to 2·2. Lustre metallic. Colour and streak black to dark steel-grey; flexible in thin laminæ; very sectile; feels greasy; leaves a mark on paper of its own colour; conducts electricity. B.B. burns with difficulty; heated with nitre, deflagrates. C.c.: carbon, with small quantities of volatile matter, and ash from 5 to 40 per cent. Strathfarrer (Inverness-shire), Mull, Craigman (Ayrshire), Borrowdale in Cumberland, Ural Mountains, Ceylon, Greenland. Used for making pencils.

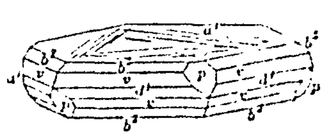


Fig. 263.

15. Tin, Sn.

Tetragonal in greyish white metallic grains. Reported as occurring with Siberian gold; with bismuthite from Guanajuato in Mexico.

16. Iron, Fe.

Cubic; in grains and plates or disseminated. H. = 4·5; G. = 7 to 7·8. Steel-grey or iron-black. Fracture hackly, very magnetic. B.B. infusible. Sol. in h. acid. Two varieties are to be distinguished. (*a*) *Telluric Iron*, in grains and plates. Almost pure iron, or contains graphite, carbon, lead, or copper, but no nickel. At Chotzen in Bohemia in limestone; in an argillaceous sandstone in the keuper at Mühlhausen; in Thuringia along with fossils; in an ironstone conglomerate in Brazil, and in lava in Auvergne; in the mine of Hackenburg; at Bexley, in Liberia, Africa, along with quartz, a zeolite, and magnetite; enclosed in magnetite in Unst (Shetland) and in Sutherlandshire; in basalt in Antrim, Ireland; in the gold sands of Brazil, the Urals, and Olahpian (Transylvania). (*b*) *Meteoric iron*, steel-grey to silver-white. Native metals.

Almost always contains nickel, with cobalt, copper, and several minerals which are non-terrestrial. When polished and etched with nitric acid the surface is marked by lines of unaffected interlacing crystals called Widmannstätten's figures; most of the nickel is contained in these. Occurs in masses which vary in size from the smallest microscopic dust as dredged from the depths of the ocean to upwards of 32,000 lb. Many of these masses have been seen to fall. Several (suspected, however, to be terrestrial) have been found imbedded in a basaltic rock near Disco Bay in Greenland, one of which is 44,000 lb in weight. Several contain hydrogen in their pores, condensed to the extent of eight times the volume of the mass; and the pitted depressions frequently observable upon their surface give countenance to the view that, if not discharged from a volcanic throat, they were set at liberty by some sudden disrupting gaseous explosion.

17. Zinc, Zn.

Rhombohedral. Said to be found in large hexagonal pyramids. Cl. basal, perfect. H. = 2; G. = 7. Lustre metallic. Colour and streak bluish white. Found in a geode in basalt near Melbourne, Australia, coated with smithsonite, erythrine, and aragonite. Also in the gold sands of the Mittamitta river.

18. Copper, Cu.

Cubic (figs. 28, 30, 26, 33, 37, 264). Twins, on an octahedral face. Crystals generally distorted. Often filiform and arborescent, or in plates and laminæ. H. = 2·5 to 3; G. = 8·5 to 8·9. Lustre dull metallic. Colour and streak copper-red, with yellow or brown tarnish. B.B. easily fusible, colouring the outer flame green. Sol. in n. acid. Occurs in many rocks (generally igneous), and frequently associated with zeolites. In the Faroes, Unst (Shetland), Cornwall, Chessy near Lyons, the Banat (Hungary), Siberia, China, Mexico, Brazil, Chili, and Australia. Masses of great size are found, much the largest being from the Ontanagon river, on the south of Lake Superior. One mass found in February 1857 was 45 feet in length, 22 feet in width, and 8 feet in thickness; its weight was 420 tons. Another was found in 1869, 65 feet in length, 32 in width, and from 4 to 7 feet in thickness; this weighed upwards of 1000 tons, and had a value of 400,000 dollars.

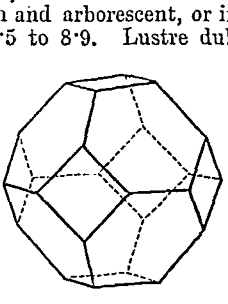


Fig. 264.

19. Lead, Pb.

Cubic, but only in thin plates, capillary or filiform. Cl. none. H. = 1·5; G. = 11·36 to 11·4. Ductile, malleable, and sectile. Bluish grey, but with a blackish tarnish. Found in lava in Madeira, and at the mines near Cartagena in Spain; in amygdaloid near Weissig; in basaltic tufa at Rautenberg in Moravia; with gold near Mount Alatau in the Altai, at Velika in Slavonia, and at Olahpian in Transylvania; near Ekaterinburg in the Urals; in the district of Zomelahuacan in Vera Cruz, in foliated galena, in granular limestone; in the iron and manganese bed of Paisberg in Wermland (Sweden), with hæmatite, magnetite, and hausmannite; in white quartz, north-west, near the Dog Lake of the Kaministiquia, an affluent of Lake Superior; imbedded in hornstone in plates and grains, in the mine of Bogoslovskoi in the Kirghiz steppes; in greenstone porphyry at Stützerbach in Thuringia; with hæmatite in the islands of Nias on the west coast of Sumatra.

20. Mercury, Hg.

Cubic. Occurs in small liquid globules in its gangue, but may be solidified at −39°, when it forms octahedral crystals. G. = 13·596 when liquid, 15·612 when solid. Lustre brilliant metallic; tin-white. B.B. volatile, sometimes leaving a little silver. Readily sol. in n. acid. Occurs generally in clay shales or schists of different ages. The globules of mercury are usually found in rents in cinnabar, or accompanying calomel, at most of the localities for these minerals. Found at Idria in Carniola and Almaden in Spain. At Idria it is obtained by washing a soft clay slate. In Transylvania and Galicia springs issuing from the Carpathian sandstone bear along globules of mercury. At the Pioneer mine in California some of the quartz geodes contain several pounds of mercury. At Cividale in Lombardy it is found in an Eocene marl. It has also been observed occasionally in drift, and has even been stated to have been found in a peat bog.

21. Silver, Ag.

Cubic (figs. 26, 30, 33, 40, 37). Crystals generally small, also and most frequently filiform, arborescent, and in plates or crusts. These either project into cavities, coat their surfaces, or ramify in a reticulated manner throughout the mass of the rock. Twins of octahedral and trapezohedral composition. No cl. H. = 2·5 to 3; G. = 10·1 to 11·1. Lustre metallic. Colour and streak silver-white, but generally tarnished yellow, brown, or black. Malleable, ductile, and sectile, but less so than gold. B.B. easily fusible. Sol. in n. acid; the solution colours the skin black. C.c.: silver, with varying proportions of gold, platinum, mercury, copper, antimony, and bismuth. The auriferous from Norway contains silver 72, gold 28; from quartz reefs in Sutherland, silver 71·4, gold 28·6. The cupriferous from Courcy near Caen contains 10 per cent. of copper. The antimonial from Bohemia contains 1 per cent. of antimony. The mercurial from Kongsberg in Norway has ·4 of mercury, found chiefly in veins in gneiss, clay slate, and limestone. Localities: Alva and elsewhere in Scotland, Ballycorus in Ireland, and Cornwall in England; at Freiberg, Andreasberg, and Kongsberg; along with native copper at Lake Superior; in Mexico, in Peru, and in the United States. The finest crystallized silver occurs at Lake Superior, and at Kongsberg. At the last locality the crystals are an inch in diameter, and are disposed on large filiform brushes. Silver occurs in large masses; three of 436, 560, 812 lb have been recorded from Kongsberg. A block which smelted 44,000 lb was for some years used as a table by Duke Albert on his annual visits of inspection to the Schneeberg mine in Saxony. A Mexican specimen was found of 400 lb; the mines of Huantaya in Peru have yielded masses of 444 and 960 lb. Britain produces annually about 760,000 oz. of silver, chiefly, however, from lead ores. The value of annual produce for the whole world from all sources is from 8 to 10 millions of pounds sterling.

22. Schneiderite (*Gold Amalgam*), Au_2Hg_3.

Tetragonal four-sided prisms, easily crumbling, yellowish white to white; sometimes in grains the size of a pea. C.c.: gold 41·63, mercury 58·37. Found at Mariposa in California. A variety $(Au, Ag)_2 Hg_5$ is found along with platinum in Columbia; this contains gold 38·39, silver 5, mercury 57·40.

23. Arquerite, Ag_6Hg.

Cubic. In octahedra, also in grains and dendrites. G. = 10·8. Like native silver, but softer. C.c.: silver 86·5, mercury 13·5. From Arqueros in Coquimbo, Chili. *Kongsbergite*, $Ag_{18}Hg$, occurs at Kongsberg, with 95·1 of silver and 4·9 of mercury.

24. Amalgam, $Ag.Hg_2$, and $AgHg_3$.

Cubic (fig. 33, in combination with 40, 30, 41, 38). Cl. dodecahedral. H. = 3 to 3·5; G. = 10·5 to 14. Colour and streak silver-white. Fracture conchoidal, brittle, grates when cut. In closed tube yields mercury and leaves silver. Sol. in n. acid. The first variety (silver 34·8, mercury 65·2) occurs at Moschellandsberg in the Palatinate, where the veins of mercury and silver intersect one another; the second (silver 26·25, mercury 73·75) there, and also at Allemont in Dauphiné, Almaden in Spain, in Hungary, and in Sweden. From Rosilla in Atacama (Chili) Domeyko reports the following other compounds: Ag_3Hg_4, silver 46·8, mercury 53·2, white and silvery; $AgHg$, silver 55·1, mercury 44·9, granular and dull; Ag_5Hg_3, silver 64·2, mercury 35·8; of the last there is a mass weighing 22 lb in the museum of Santiago.

25. Gold, Au.

Cubic (figs. 30, 26, 33, 40, 36) and more complex forms. Crystals generally small and indistinct through elongation, assuming capillary and arborescent shapes. Also in thin plates. Twins rare; twin face octahedral. Frequently in rounded and apparently colloidal masses impacted in clay, or loose in small grains (pipettes) rolling in the bed of streams. Fig. 265 is of such a mass found in Sutherland. No cl. H. = 2·5 to 3; G. = 17 to 19·4. Lustre metallic, but frequently dull and partly coated with a brown crust. Colour and streak yellowish white to bright gold-yellow. Malleable, ductile, and sectile; the purer varieties the more so and the softer. B.B. easily fusible. Sol. in aqua regia, generally with precipitation of chloride of silver. Solution yellow, stains skin purple-red, with corrosion. C.c.: gold, with silver from ·72 to 26 per cent.; sometimes iron and copper under 1 per cent. Found in beds and veins generally of quartz in metamorphic rocks of a schistose nature, rarely in diorite and porphyry, and very rarely in granite. Its general associate is limonite, formed from decomposition of pyrite; sometimes also hæmatite and magnetite. Occurs also in microscopic grains in quartz, from which it is extracted by crushing and amalgamation. The geologic range is from the Azoic to the Tertiary and Cretaceous, as in California; but even in these more recent rocks the original source must have been at least Palæozoic. Of localities which yield gold the following may be noticed:—the Leadhills in Scotland, Wicklow in Ireland, Dolgelly in North Wales, Cornwall in England; Transylvania, Hungary, and Piedmont; the Urals, Ekaterinburg, and India; Kordofan, the coast opposite Madagascar, and the Gold Coast (the fame of which has been recently revived); Minas Geraes in Brazil, Bolivia, North Carolina, and

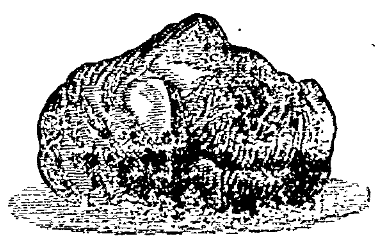


Fig. 265.

California; and more recently New South Wales and Queensland in Australia, Tasmania, and New Zealand.

Some of the largest single masses of gold found in recent times are the following:—one of 22 oz. in Transylvania, of 28 lb in North Carolina, of 20 lb in California, one of 96 lb troy near Miask in the Urals, and one of 184 lb 8 oz., which yielded £8376, 10s. 6d., at Ballarat, Australia.

The annual produce of gold from Australia is about 5 millions of pounds sterling, of the United States about 15 millions, and the whole earth about 23 millions.

The following sub-species may be noticed:—

1. *Electrum.* This name for the alloys of gold and silver was applied by Pliny, whenever the proportion of the latter metal was one-fifth. An alloy of 2 gold and 1 silver contains 21 per cent. of silver; this is found in Sutherland. One of 1 to 1 contains 36 per cent. of silver, this last being the most usual proportion. It occurs in Transylvania, in the Altai, and in Colombia. Its colour is brass-yellow to yellowish white. G. = 12·5 to 15·5.

2. *Porpezite*, or *Palladium Gold* (*ouro-poudré*), from Porpez in Brazil, contains 9·85 per cent. of palladium and 4·17 of silver.

3. *Rhodium Gold*, from Mexico (G. = 15·5 to 16·8), contains from 34 to 43 per cent. of rhodium.

26. Platinum, Pt.

Cubic; rarely in small cubes or octahedrons, usually in minute scaly grains, sometimes cohering, and also in rounded lumps. No cl. H. = 4 to 4·5; G. = 17 to 19. Lustre metallic. Colour and streak pale steel-grey. Malleable and ductile with difficulty, having a hackly fracture. When containing much iron, magnetipolar. B.B. infusible. Sol. in aqua regia, but only when heated; solution red; corrodes the skin. C.c.: platinum, but never to a greater extent than 86·5 per cent. The remainder consists of iron, iridium, rhodium, palladium, osmium, gold, copper, and a mechanical mixture of iridosmine. The iron exists in quantities varying from 4·3 per cent. to double that amount. Occurs in Brazil in syenite; near Popayan (Colombia) in alluvium, associated with chromite, iridium, palladium, gold, and copper; in the Urals in alluvium derived from crystalline rocks; and at Nijni-Tagilsk in serpentine along with chromite. It is also found in Borneo, California, and Carolina, and is said to have been found in the county of Wicklow in Ireland. The sands of many rivers yield it in small amount. Platinum does not occur in large masses. A mass in the Madrid Museum from Condoto weighs 26½ oz.; masses have been found in the Urals from 11 to 21 lb.

Iron Platina is a sub-species. This, which has a composition $FePt_2$, and contains from 11 to 13 per cent. of iron, is found at Nijni-Tagilsk. G. = 14·6 to 15·8; H. = 6. It is magnetipolar, and attracts iron much more strongly than an ordinary magnet.

27. Platiniridium.

In minute silver-white grains. H. = 6 to 7; G. = 16·94 to 22·8. Contains 55·44 platinum, 27·79 iridium, 6·86 rhodium, 4·14 iron, 3·3 copper, ·49 palladium. Is found in Brazil.

28. Iridium, Ir.

Cubic (fig. 27). H. = 6 to 7; G. = 21·57 to 23·46. Cl. cubic, traces. Very slightly malleable. Silver-white to steel-grey. B.B. unchanged. Insoluble in all acids. C.c.: 76·8 iridium, 19·64 platinum, 0·89 palladium, 1·78 copper. Found at Nijni-Tagilsk, generally in minute grains. Is the heaviest known substance.

Avaite, sub-species. From Ava in India. C.c.: 60 iridium, 20 platinum (according to Prinsep).

29. Palladium, Pd.

Cubic; in minute octahedrons, and in grains. H. = 4·5 to 5; G. = 11·3 to 11·8. Malleable. Light steel-grey. B.B. infusible. Slowly dissolves in n. acid, forming a brown-red solution. C.c.: palladium, with a little platinum and iridium. From the gold sands of Brazil, often in small plumose crystalline lumps. Also from St Domingo, and the Urals. Does not tarnish with sulphurous fumes.

30. Allopalladium, Pd_3.

Hexagonal; in small flat hexagons. Cl. basal, perfect. Lustre bright silvery. Colour pale steel-grey. From Tilkerode in the Harz, with gold.

31. Newjanskite (*Osmiridium*), IrOs (iridium 49·78, osmium 50·22) and Ir_3Os.

Hexagonal; P 124°. 0P, P, ∞P. Generally in flat scales. Cl. basal perfect. H. = 7; G. = 18·8 to 19·47. Lustre metallic. Colour tin-white. B.B. unchanged. Insoluble in all acids. The analyses of this mineral give quantities of iridium varying from 44 to 77 per cent., and of osmium from 21 to 49. Ruthenium, rhodium, and platinum make up the 100 parts. The largest quantity of ruthenium is 8·49, and one variety from New Granada was found to contain no ruthenium, but 12·3 of rhodium, which is more than double its usual amount. Occurs with platinum in Choco (Colombia); at Newjansk and several localities in the Urals, in Australia, in northern California (somewhat abundantly in gold sands), also in Canada.

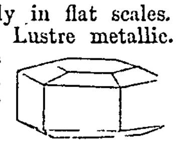


Fig. 266.

32. Sisserskite (*Iridosmium*), $IrOs_4$ (iridium 19·9, osmium 80·1) and $IrOs_3$ (iridium 24·8, osmium 75·2).

Rhombohedral; R = 84° 28′. H. = 7·5; G. = 21·12. Colour lead-grey to bluish. B.B. becomes black, with strong odour of osmic acid; in flame of spirit-lamp shines strongly, and colours flame yellowish red. Occurs in small quantity with newjanskite at all its localities, and in proportionally larger quantity at Sissersk in the Urals. It is used for pointing gold pens, and in the United States sells at 50 dollars an ounce.

COMPOUNDS OF FLUORINE, CHLORINE, BROMINE, AND IODINE (HALOID SALTS).

33. Fluorite (*Fluor-spar*), CaF.

Cubic (figs. 267 to 270, also figs. 31, 33, 36, 55, 56, 57, 58); also divergent crystalline, granular, and compact. Cl. octahedral; fracture conchoidal; brittle. H. = 4; G. = 3·1 to 3·2. Transparent to pellucid. Lustre vitreous. Colourless, but generally coloured purple, blue, green, yellow, white, black, and pink. Sometimes two or three colours disposed in layers in one crystal. Frequently phosphoresces with different tints of light, when heated. B.B. decrepitates and fuses to an opaque bead. Sol. in s. acid with evolution of hydrofluoric acid. C.c.: 51·3 calcium, 48·7 fluorine. Common in veins, generally associated with metallic ores. Shetland, Sutherland, on the Avon, and Ballater in Scotland; Cumberland, Northumberland, Derbyshire, and Cornwall; Saxony, Bohemia, Freiberg. Used to be turned into vases and other ornaments ("blue John"); formerly employed as a flux, now for etching and obscuring glass.

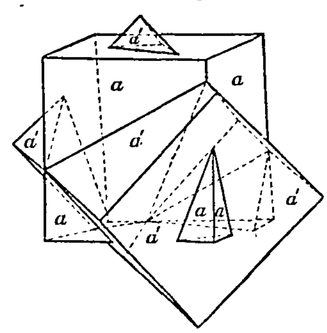


Fig. 267.

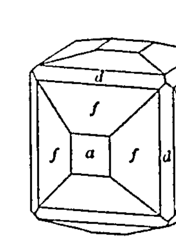


Fig. 268.

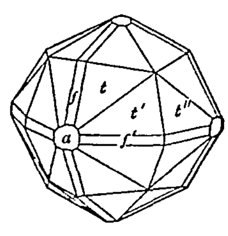


Fig. 269.

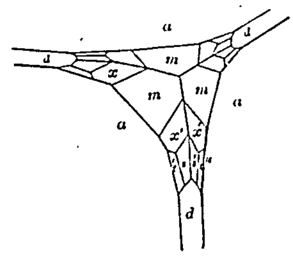


Fig. 270.

34. Yttrocerite.

In crystalline crusts. H. = 4 to 5; G. = 3·4 to 3·5. Translucent; vitreous. Violet-blue to grey or white. B.B. infusible. Evolves fluorine when heated with sulphuric acid. C.c: fluorides of cerium, yttrium, and calcium. Finbo and Broddbo near Falun (Sweden), Massachusetts and New York.

35. Fluocerite, $CeF + Ce_2F_3$.

Hexagonal. H. = 4 to 5; G. = 4·7. Opaque or translucent on the edges. Pale brick-red or yellowish; streak yellowish white. B.B. infusible. In closed tube gives out hydrofluoric acid. C.c.: 82·64 peroxide of cerium, 1·12 yttria, 16·24 hydrofluoric acid. Finbo and Broddbo.

36. Fluocerine, $Ce_2F_3 + (Ce_2O_3 + H_2O)$.

Massive; fracture conchoidal. H. = 4·5 to 5. Opaque; resinous. Bright yellow to reddish brown; streak brownish yellow. B.B. infusible, darkens with the heat; colour restored on cooling. C.c.: cerium 17·6, fluorine 10·9, sesquioxide of cerium 66·4 water 5·1. From Finbo.

37. Bastnaesite, $Ce_2F_3 + Ce_2O_3 + 4H_2O$, and

38. Hamartite, $2(LaO, CeO)3CO_2 + CeF_3$, are similar. The first is from Bastnaes in Sweden, the second from Pike's Peak in Colorado.

39. FLUELLITE, Al_2F_3.

Right prismatic. In acute rhombic octahedrons with truncated apex. Polar edges 109° 6′ and 82° 12′, middle 144°. H. = 3. Lustre vitreous. Colour white; transparent. Stenna-gwyn in Cornwall.

40. CRYOLITE, $3NaF + Al_2F_3$.

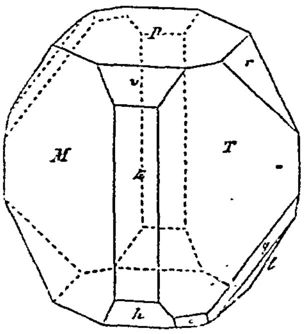


Fig. 271.

Anorthic; but mostly in cleavable masses. $M : T$ 91° 57′; $P : T$ 90° 2′; $P : M$ 90° 40′. Cl. P perfect, M and T imperfect; brittle. H. = 2·5; G. = 2·9 to 3·08. Vitreous, somewhat pearly on P. Translucent; after immersion in water transparent. Colourless and snow-white; but when deep-seated brown to black. Melts even in flame of candle to a white enamel. In open tube traces of hydrofluoric acid. Sol. in s. acid. C.c.: aluminium 13, sodium 32·8, fluorine 54·2. Arksutfiord, Greenland; Miask, Siberia. Used for manufacture of a white glass, and extraction of aluminium.

41. ARKSUTITE, $(CaNa)_2F + Al_2F_3$. Ca : Na = 1 : 3.

Massive granular. H. = 2·5; G. = 3·03 to 3·18. Cl. one distinct. Vitreous; white; translucent. C.c.: aluminium 18·6, sodium 23·3, calcium 6·8, fluorine 51·3. Arksutfiord.

42. CHIOLITE, $3NaF + 2Al_2F_3$.

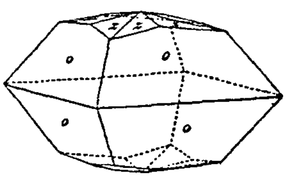


Fig. 272 (species 42).

Pyramidal, and twins (fig. 272). Middle edge 111° 14′. Mostly granular. Cl. imperfect. H. = 4; G. = 2·84 to 2·9. Resinous; white. Fuses more easily than cryolite; evolves hydrofluoric acid. C.c.: aluminium 18·6, sodium 23·4, fluorine 58. Ilmen Mts. near Miask.

43. CHODNEFFITE, $2NaF + Al_2F_3$.

G. = 3. Other characters like chiolite, and from same locality.

44. PACHNOLITE, $3(CaNa)F + Al_2F_3 + 2H_2O$. Ca : Na = 3 : 2.

Oblique prismatic. ∞P 98° 34′; always twins. Vitreous; white; semitransparent. C.c.: aluminium 12·3, calcium 16·1, sodium 12·4, fluorine 51·1, water 8·1. Evolves water with crackling, when heated; other characters like cryolite, along with which it occurs in Greenland.

45. THOMSENOLITE, $2(CaNa)F + Al_2F_3 + 2H_2O$. Ca : Na = 7 : 3.

Oblique prismatic. Prismatic planes striated; ∞P 89° (fig. 273). Cl. basal, perfect. H. = 2·5 to 4; G. = 2·74 to 2·76. Vitreous; cleavage face pearly. White with yellow crust; translucent. C.c.: aluminium 15, calcium 15·4, sodium 7·6, fluorine 52·2, water 9·8. B.B. fuses more easily than cryolite to clear glass, decrepitating violently. Along with cryolite in Greenland.

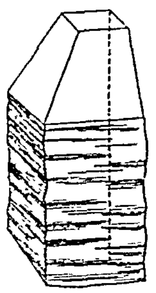


Fig. 273 (sp. 45).

46. GEARKSUTITE, $Ca_2F + Al_2F_3 + 4H_2O$.

Earthy. H. = 2. White; dull; opaque. C.c.: aluminium 15·5, calcium 19·3, sodium 2·5, fluorine 41·2, water 20·3. Along with cryolite.

47. EVIGTOKITE, $2CaF_2 + Al_2F_6 + 2H_2O$.

Crystalline. Soft; brittle; like kaolin. C.c.: calcium 22·39, aluminium 16·23, sodium ·43, fluorine 55·24, water 5·71. Arksutfiord, Greenland.

48. PROSOPITE.

Oblique prismatic. A hydrated silico-fluoride of aluminium and calcium. H. = 4; G. = 2·89. Colourless imbedded crystals. From the tin-mines of Altenberg.

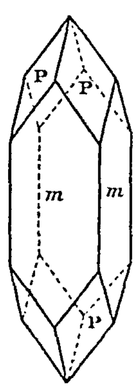


Fig. 274 (sp. 49).

49. CALOMEL, Hg_2Cl.

Pyramidal; P 135° 50′ (fig. 274). H. = 1 to 2; G. = 6·4 to 6·5. Translucent; adamantine. Yellowish white to grey. Sublimes unchanged in closed tube; with soda yields mercury. Insol. in n. acid. C.c.: mercury 85, chlorine 15. Moschellandsberg, Idria, Almaden.

50. SYLVITE, KCl.

Cubic (figs. 26, 30); also massive. Cl. cubic. H. = 2; G = 1·9 to 2. White or colourless. Vitreous; soluble; taste like common salt. C.c.: potassium 52·5, chlorine 47·5. B.B. fuses, and colours flame violet. Crater of Vesuvius, and salt beds of Stassfurt.

51. HALITE (*Common Salt*, *Rock-salt*), NaCl.

Cubic (fig. 21); generally granular, sometimes fibrous. Cl. cubic. H. = 2; G. = 2·1 to 2·2. Transparent to translucent; vitreous. Colourless or white; but often coloured red, yellow, or blue. Taste saline. B.B. fuses and partly evaporates; colours flame yellow. C.c.: sodium 39·3, chlorine 60·7. In great beds at Wieliczka, Salzburg, Bex, &c., on the Continent; Cheshire in England. As an efflorescence in Brazil, Abyssinia, the Caspian and Aral Seas. As a sublimation among lavas at Vesuvius and other volcanoes.

52. SALMIAC, NH_4Cl.

Cubic (figs. 30, 40, and 41 with 26, 33, 40). Cl. octahedral; also stalactitic, globular, and as an efflorescence. H. = 1·5 to 2; G. = 1·5 to 1·6. Pellucid; vitreous. Colourless, but sometimes stained. Taste pungent. B.B. directly volatile; in copper colours flame blue-green. C.c.: 32 ammonia, 66·4 chlorine. A sublimate on active volcanoes. Vesuvius, island of Volcano, Iceland. Near coal-seams which have taken fire, in Scotland and at Newcastle.

53. CHLORO-CALCITE, CaCl + (KCl, NaCl).

Cubic. Vesuvian bombs.

54. CERARGYRITE, AgCl.

Cubic (fig. 26). Twins on octahedral face. No cl.; chiefly massive in crusts. H. = 1 to 1·5; G. = 5·5 to 5·6. Fracture conchoidal. Malleable. Translucent; adamantine to resinous. Grey, yellowish, and greenish. B.B. fuses easily to a dark bead, reduced in inner flame. Soluble in ammonia. C.c.: silver 75, chlorine 25. Johann-Georgenstadt, Mexico, Peru.

55. EMBOLITE, 2AgBr + 3AgCl.

Cubic (fig. 29); also massive or concretionary. H. = 1 to 1·5; G. = 5·8. Adamantine to resinous. Green and yellowish green. C.c.: silver 67, chlorine 13, bromine 20. Chili, Mexico, Honduras.

56. BROMITE, AgBr.

Cubic (figs. 26, 30). H. = 1 to 2; G. = 5·8 to 6. Splendent. Yellow to olive-green; streak siskin-green. B.B. fusible easily. C.c.: silver 57·5, bromine 42·5. San Onofre and Plateros (Mexico).

57. IODITE, AgI.

Hexagonal. Cl. basal; also massive, and in crystalline plates some inches in width; these are flexible. H. = 1 to 1·5; G. = 5·5 to 5·7. Translucent; adamantine. Citron and sulphur-yellow; streak yellow. B.B. fusible, colours the flame purple-red, and leaves button of silver. C.c.: silver 46, iodine 54. Zacatecas in Mexico, Algodones in Chili, Arizona, rarely in Spain.

58. COCCINITE, HgI_2.

In grains of an adamantine lustre, from Casas-Viejas in Mexico. Colour red to yellow; in acute rhombic prisms. Also from Zimapan and Culebras.

59. TOCORNACLITE, $AgI + Hg_2I$.

Amorphous, yellow, soft. Chañarcillo in Chili.

60. COTUNNITE, PbCl.

Right prismatic. H. = 2; G. = 5·238. Transparent; high adamantine to pearly. White. C.c.: lead 74, chlorine 26. Crater of Vesuvius.

61. MOLYSITE, Fe_2Cl_3.

Incrusting. Brownish red and yellow. On lavas of Vesuvius. C.c.: iron 34·5, chlorine 65·5.

62. CARNALLITE, $KCl + 2MgCl + 12H_2O$.

Right prismatic. No cl. Conchoidal fracture. H. = 2 to 2·5; G. = 1·6. Colourless, generally red from iron. C.c.: 34·2 chloride of magnesium, 26·9 chloride of potassium, 38·9 water. Stassfurt, Galicia, Persia.

63. TACHHYDRITE, $CaCl + 2MgCl + 12H_2O$.

Massive. Yellow, translucent, very deliquescent. In anhydrite. C.c.: calcium 7·46, magnesium 9·51, chlorine 40·34, water 42·69. Stassfurt.

64. KREMERSITE, $KCl + NH_4Cl + Fe_2Cl_3 + 3H_2O$.

Cubic; in octahedra. Ruby-red. Soluble. Fumaroles of Vesuvius.

65. ERITHROSIDERITE, $2KCl + Fe_2Cl_3 + 2H_2O$.

Right prismatic. Vesuvian lava.

66. MATLOCKITE, PbCl + PbO.

Pyramidal; P 136° 17′. Crystals tabular. Cl. basal; fracture conchoidal. H. = 2·5; G. = 7·21. Translucent; adamantine. Yellowish white. B.B. fuses easily with decrepitation; colours flame blue. C.c.: chloride of lead 55·5, oxide of lead 44·5. Cromford in Derbyshire.

67. MENDIPITE, PbCl + 2PbO.

Right prismatic; chiefly massive. Cl. ∞P perfect 102° 36′. H. = 2·5 to 3; G. = 7· to 7·1. Fracture conchoidal. Translucent; adamantine to pearly. Yellowish or greyish white. BB. decrepitates, fuses

easily. Sol. in n. acid. C.c.: chloride of lead 40, protoxide of lead 60. Mendip Hills, and Brilon in Westphalia.

68. SCHWARTZEMBERGITE, $PbI + 2PbO$.

Rhombohedral; in thin crusts. H. = 2 to 2·5; G. = 5·7 to 6·3. Adamantine. Honey-yellow. Desert of Atacama.

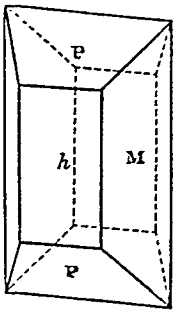


Fig. 275 (sp. 69).

69. ATACAMITE, $CuCl + 3CuO, H_2O$.

Right prismatic; ∞P (*M*) 112° 25′, $\breve{P}\infty$ (*P*) 106° 10′, $\infty\breve{P}\infty$ (*h*) (fig. 275); also reniform. Cl. h perfect. Semitransparent; vitreous. Emerald-green; streak apple-green. B.B. fuses, leaving copper. Easily soluble in acids. C.c.: copper protoxide 55·85, copper 14·86, chlorine 16·61, water 12·68. Atacama, Chili; Tarapaca, Peru; Bolivia; Burra-Burra, Australia; Serra de Bembe, Ambriz, Africa; Vesuvius and (?) Etna.

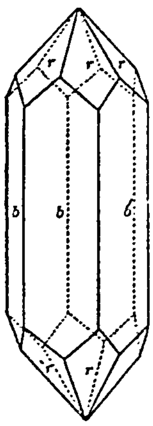


Fig. 276 (sp. 72).

70. TALLINGITE, $CuCl, H_2O + 4CuO, H_2O$.

In crusts. H. = 3; G. = 3·5. Bright blue to greenish blue. Translucent; brittle. Botallack in Cornwall.

71. PERCYLITE, $(PbCl + PbO) + (CuCl + CuO)$.

Cubic (com. of figs. 26, 30, 33, 36). H. = 2. Vitreous. Sky-blue. Sonora in Mexico.

72. CONNELLITE.

Hexagonal (fig. 276). $b : r$ 143° 10′; $r : r$ 132° 50′. Crystals acicular. Vitreous; translucent. Vitriol-blue. A chloride and sulphide of copper. Wheal Unity and Wheal Damsel (Cornwall).

OXIDES OF METALS.

1. SUBOXIDES AND PROTOXIDES.

73. CUPRITE, Cu_2O.

Cubic (figs. 22, 30, 33, 26, with 39, 40). Compact and granular. Cl. octahedral; brittle. H. = 3·5 to 4; G. = 5·7 to 6. Transparent and opaque; adamantine. When transparent, crimson; when opaque, cochineal or brick-red. Often tarnished grey. B.B. becomes black, fuses, and is reduced on charcoal. Soluble in acids and in ammonia. C.c.: 88·9 copper, 11·1 oxygen. Cornwall, Siberia, Banat, Chessy near Lyons, Linares in Spain, Urals, South Africa, Burra-Burra. Valuable copper ore. *Chalcotrichite* consists of cubes elongated so as to become fibrous. Tile-ore is a ferruginous variety. Hepatic copper, liver ore, or pitchy copper ore seems to be a product of the decomposition of chalcopyrite. *Delafossite*, $Cu_2O + Fe_2O_3$, from Bohemia and Siberia.

74. WATER, H_2O.

Hexagonal, when solid, in complex twins in snow crystals; rhombohedric by cleavage, in ice. H. = 1·5; G. = ·918. Hence 1000 of water = 1089·5 of ice, or water expands $\frac{1}{11}$th in freezing. Transparent; vitreous. Colourless, but in bulk pale emerald-green. R 117° 23″. Cl. basal. Water when pure colourless, in mass bluish green. Occurs in centre of geodes of chalcedony in China; of druses of quartz in California and many other countries; in zeolitic cavities to the amount of several gallons in the Faroes, also in the Hebrides, &c. Water of the ocean, from holding saline matters in solution, has G. = 1·027 to 1·0285. Waters of saline lakes contain sometimes 26 per cent. of salts, and have G. 1·212. Besides its vast bulk in the ocean, water occurs in enormous amount in the solid form, often as water of crystallization in rocks and minerals, *e.g.*, zeolites. Igneous rocks in some districts are converted largely into saponite, which contains 25 per cent. of water. Water is the standard for specific gravities of solids and liquids; 1 cubic inch at 60° F. and 30 inches of the barometer weighs 252·458 grains: 1 litre weighs 1000 grammes.

75. PERICLASE, MgO.

Cubic; in cubes and octahedrons. Cl. do. H. = 6; G. = 3·6 to 3·75. Transparent; vitreous. Grey to dark green. B.B. infusible. Sol. in acids. C.c.: magnesia, with 6 to 8 of iron oxide. Somma.

76. BUNSENITE, NiO.

Cubic; in octahedrons. H. = 5·5: G. = 6·4. Vitreous. Pistachio-green. Johann-Georgenstadt.

77. ZINCITE, ZnO.

Hexagonal and granular. Cl. basal. H. = 4 to 4·5; G. = 5·4 to 5·5. Adamantine; translucent. Blood- or hyacinth-red; streak orange-yellow. B.B. infusible, but phosphoresces. C.c.: zinc 80·26, oxygen 19·74; sometimes with manganese peroxide. Valuable ore of zinc. Franklin and Sterling in New Jersey.

78. MASSICOT, PbO.

Massive; scaly crystalline. H. = 2; G. = 7·8 to 8. Sulphur- or lemon-yellow; often contains iron. Popocatepetl in Mexico.

79. MELACONITE, CuO.

Cubic; compact. H. = 3 to 4; G. = 6 to 6·3. Black. B.B. infusible; soluble in acids. Cornwall, Leadhills, Lake Superior, Burra-Burra.

80. TENORITE, CuO.

Oblique prismatic; occurs in thin scales of metallic lustre on lava of Vesuvius. Colour black and dark-red.

2. SESQUIOXIDES.

81. CORUNDUM, Al_2O_3.

Hexagonal; R 86° 4′. Twins common. Cl. rhombohedral, and basal. Excessively tough, and difficultly frangible. H. = 9; G. = 3·9 to 4·2. Transparent or translucent; vitreous, but pearly to metallic on basal face. B.B. unchanged. As *Corundum*, white, grey, and greenish, frequently with bronzy lustre on basal face. C.c.: alumina, with a little peroxide of iron. China, Ceylon, Bohemia, Malabar, Macon in North Carolina (one crystal 300 lb weight). *Emery* is compact, crystalline, granular; grey to indigo-blue. Asia Minor, Naxos, Spain, Greenland, America. Corundum is used when crushed for cutting and polishing gems in China and India, emery in powder for grinding. Alumina occurs also in a purer state in transparent crystals of various tints of colour. When red and of the colour of pigeon's blood they are termed *Rubies*; these come from Syriam in Pegu, Ava, Ceylon, Bohemia, and near Expailly. When 5 carats in weight a ruby is twice the value of a diamond of the same size, when 10 carats three times the value. When blue the crystal is the *Sapphire*, found chiefly in Ceylon and Pegu; when green it is the *Oriental Emerald*, when yellow the *Oriental Topaz*, when purple the *Oriental Amethyst*,—the adjective here distinguishing them from the true or occidental stones of the same name. Other tints of colour also occur, but with the exception of the red and blue they are seldom pure or deep. The prism when cut with a hemispherical dome sometimes displays a six-rayed star, either of a bright gold or a silvery white colour, upon a greyish blue ground. These receive the name of *Asteria Sapphires*. The same crystal frequently shows portions of even three different tints. When perfectly devoid of colour, they are called *Water Sapphires*; such are little inferior to the diamond in brilliancy, but do not disperse rays of light to the same extent.

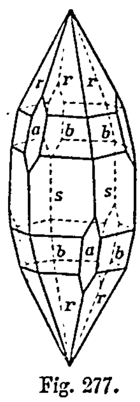


Fig. 277.

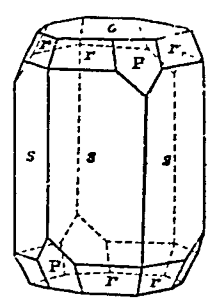


Fig. 278.

82. HÆMATITE, Fe_2O_3.

Hexagonal and rhombohedral; R 86°. Crystals rhombohedric, prismatic, and tabular. Twins with axes parallel. Cl. R, and basal; fracture conchoidal; brittle. H. = 5·5 to 6·5; G. = 5·1 to 5·3. Opaque, but in thin laminæ transparent and blood-red. Brilliant metallic lustre, iron-black to steel-grey, often brilliantly tarnished of red, yellow, green, and blue tints; streak cherry-red. B.B. in the inner flame becomes black and magnetic. Sol. in acids. C.c.: iron 70, oxygen 30. The following are varieties or subdivisions:—

Fig. 279.

Elba Iron Ore, highly modified rhombohedral crystals, often brilliantly tarnished. *Specular Iron Ore*, in thin flat crystals, often from volcanoes, as on the island of Ascension; this variety includes *Micaceous Iron*, thin, lamellar, and curved, and *Red Iron Froth*, scaly. *Red Hæmatite*, in botryoidal and stalactitic forms, which are internally composed of radiating fibres, and often have a concentric structure; the external surface has a dark red to a brownish red hue. *Compact* and *Ochrey* varieties, with more or less aluminous impurity, pass into *Reddle* or red chalk, and when still more earthy into jaspery and columnar ores. This ore is very commonly distributed:—micaceous iron at Pitfichie in Aberdeen and Birnam in Perthshire; red hæmatite at Leadhills and at

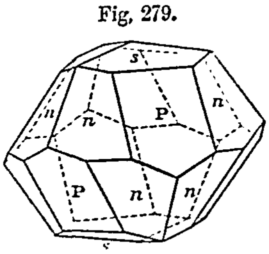


Fig. 280.

Ulverston in Lancashire; specular iron at Tavistock in Devonshire and in Cumberland. *Martite* seems to be the same substance in pseudomorphs after magnetite; it occurs in octahedra in Bute, Framont (Vosges), New York, and Brazil.

83. Ilmenite, $(Fe,Ti)_2O_3$.

Rhombohedral; R 86°. Crystals rhombohedral and tabular, also in twins. Cl. basal; fracture conchoidal. H. = 5 to 6; G. = 4·66 to 5. Opaque, semimetallic, iron-black to dark brown; streak black or reddish brown. Sometimes slightly magnetic. B.B. infusible, but with microcosmic salt forms a red glass. Slowly sol. in s. acid when powdered. C.c.: peroxide of iron, with from 8 to 53 per cent. oxide of titanium. Occurs in metamorphic rocks. Common in chloritic gneiss in Scotland; Menaccan (Cornwall), Ilmen Mountains, Salzburg, Egersund (Norway), Arendal, Dauphiné (*Crichtonite*), Massachusetts (*Washingtonite*).

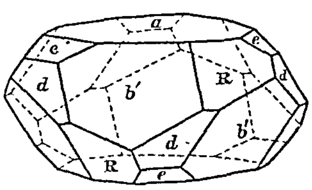


Fig. 281.

84. Iserine.

Cubic; in octahedra. Strongly magnetic; in other respects similar to ilmenite, but occurs in igneous rocks. Common as black ironsand in Scotland; Iserweise in Bohemia, Auvergne, Canada, New Zealand.

3. Compounds of Sesquioxides with Protoxides (Spinels).

85. Magnetite, FeO, Fe_2O_3.

Cubic (figs. 35, 30, 33, 29, 34, 37, with 40, 41, 36). Hemitropes common on octahedral face (fig. 169). Twins (fig. 261). Faces of ∞0 striated in long diagonal. Often compact and granular. Cl. octahedral; fracture conchoidal or uneven; brittle. H. = 5·5 to 6·5; G = 4·9 to 5·2. Opaque; lustre metallic. Iron-black to brown; streak black. Highly magnetic; often polar, forming natural magnets. B.B. becomes brown and non-magnetic, fusing with difficulty. Powder sol. in h. acid. C.c.: 31 protoxide and 69 peroxide of iron; or 72·4 iron, 27·6 oxygen; sometimes with titanic acid. In crystals in Shetland and Sutherland; also Cornwall and Antrim, Traversella (Piedmont), Tyrol, Styria. Massive at Dannemora and Taberg (Sweden), Norway, Urals, Harz, Saxony, Elba. This is the most important ore in Norway, Sweden, and Russia, and affords the finest iron.

86. Magnesio-Ferrite, MgO, Fe_2O_3.

Cubic (fig. 30). H. = 6 to 6·5; G. = 4·57 to 4·66. Other characters same as magnetite. C.c.: magnesia 20, peroxide of iron 87. Fumaroles of Vesuvius.

87. Jacobsite, (MnO, MgO), (Fe_2O_3, Mn_2O_3).

Cubic; O. Black; vitreous; streak red. Nordmark in Sweden.

88. Franklinite, (FeO, ZnO, MnO), (Fe_2O_3, Mn_2O_3).

Cubic (figs. 34, 64); also granular. Cl. octahedral; fracture conchoidal; brittle. H. = 5·5 to 6·5; G. = 5·07. Metallic lustre. Iron-black; streak reddish brown. Opaque; slightly magnetic. B.B. infusible, but shines and throws out sparks. On charcoal with soda a deposit of oxide of zinc. Sol. in h. acid with evolution of chlorine. C.c.: about 67 iron oxide, 17 manganese peroxide, 16 zinc oxide. Franklin and Sterling (New Jersey).

89. Chromite, FeO, Cr_2O_3.

Cubic; in octahedra, generally granular-massive. H. = 5·5; G. = 4·4 to 4·5. Opaque; semimetallic to resinous. Iron-black to dark brown; streak reddish brown. Fracture uneven; sometimes magnetic. B.B. unchanged; in red. flame becomes magnetic; with borax forms an emerald-green bead. Not soluble in acids. C.c.: 19 to 37 protoxide of iron, 0 to 15 magnesia, 36 to 64 peroxide of chromium, 9 to 21 alumina. Unst (Shetland), Towanrieff (Aberdeenshire), Silesia, Bohemia, Styria, Urals, Turkey, Baltimore, Massachusetts, and Hoboken. The ore of chromium; used for dyes. *Irite* is chromite mixed with iridosmium.

90. Uraninite (*Pitch Blende*), UO, U_2O_3.

Cubic (fig. 30); usually massive and botryoidal. H. = 5 to 6; G = 6·5 to 8. Lustre pitch-like to submetallic. Colour velvet-black, brownish black, and grey. B.B. infusible. Not sol. in h. acid, but easily in hot n. acid. C.c.: oxides of uranium 80, with a mixture of other oxides. Johann-Georgenstadt, Annaberg, Przibram, Redruth in Cornwall. The chief ore of uranium.

91. Gahnite, ZnO, Al_2O_3.

Cubic (figs. 166, 30, 33, and with 39, 40). Hemitropes like magnetite. Cl. O; brittle, with conchoidal fracture. H. = 7·5 to 8; G. = 4·3 to 4·9. Opaque; vitreous to resinous. Dark leek-green to blue; streak grey. B.B. unchanged. Unaffected by acids or alkalies. C.c.: 44 oxide of zinc, 56 alumina. Falun, Broddbo, Haddam in Connecticut, and Franklin in New Jersey. *Dysluite* contains 42 per cent. sesquioxide of iron; and *Kreittonite* contains 24 oxide of manganese.

92. Hercynite, FeO, Al_2O_3.

Cubic; generally granular massive. H. = 7·5 to 8; G. = 3·9 to 3·95. B.B. infusible. C.c.: oxide of iron 41·1, alumina 58·9. Ronsberg in the Böhmerwald.

93. Spinel, MgO, Al_2O_3.

Cubic (figs. 30, 33, 40 with 26); hemitropes united by face of O. Cl. octahedral; fracture conchoidal. H. = 8; G. = 3·4 to 4·1. Transparent to opaque; vitreous. Black, red, blue, green; streak white. B.B. infusible and unchanged. C.c.: 28 magnesia, 72 alumina; some with a little iron, and the red varieties some chromium. Varieties are—*Spinel Ruby* when scarlet, *Balas Ruby* when rose-red; both often sold as the true ruby, but not nearly so valuable; when of 4 carats valued at half the price of a diamond the same size. These

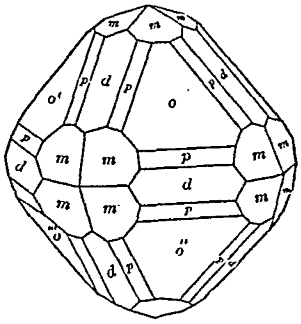


Fig. 282.

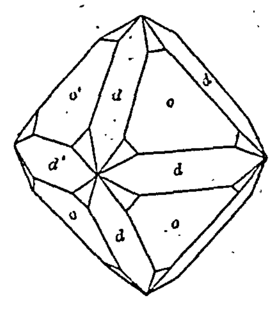


Fig. 283.

come from Pegu (native name Balachan). The violet-coloured is the *Alabandine ruby* from Alabandin in Caria, (Asia Minor). The orange red is the *Rubicella*. The above also occur at Ceylon, Ava, and Siam. *Sapphirine* is pale sapphire-blue to greenish or reddish blue; from Aker in Sweden, Greenland, and North America. *Pleonaste*, dark green or blue to black; from Candy in Ceylon. *Chlorospinel*, grass-green with a yellowish white streak; from Zlatoust. *Water-spinel* colourless; from Ceylon. *Picotite* is a dark blue chromiferous variety from serpentine.

94. Chrysoberyl, GlO, Al_2O_3.

Right prismatic (fig. 284). Twins common, united by a face of P∞ (fig. 285, also 156). Cl. brachydiagonal imperfect, macrodiagonal more so; fracture conchoidal. H. = 8·5; G. = 3·68 to 3·8. Transparent or translucent; vitreous. Greenish white, leek-green, and dark emerald-green. B.B. infusible. Not affected by acids. C.c.: glucina 20, alumina 80. Brazil, Ceylon, India, the Urals, Haddam in Connecticut. A very valuable gem. It sometimes possesses an opalescent band, which when the stone is cut *en cabochon* appears as a streak of floating light; whence it derives its name of *Cymophane*. It is then also called the chatoyant or Oriental chrysolite, and when fine is of extreme value. The emerald-green variety, or *Alexandrite*, is columbine-red by transmitted light.

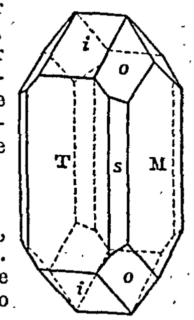


Fig. 284 (sp. 94).

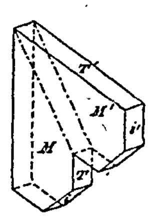


Fig. 285.

4. Deutoxides.

95. Rutile, TiO_2.

Pyramidal; prisms dominant. P 84 40′; P∞ 65° 35′ (figs. 286, 287). Hemitropes common, with axes of halves 114° 26′. Cl. ∞ P and ∞P∞, perfect. H. = 6 to 6·5; G. = 4·2 to 4·3. Transparent to opaque; adamantine lustre. Brown-red, red, pale yellow, and black; streak yellowish brown. B.B. unchanged; with borax in the ox. flame forms a greenish, in the red. flame a violet glass. Not affected by acids. C.c.: titanic acid, with some peroxide of iron. Craigcailleach and Ben-y-Gloe (Perthshire), The Cobbler and Ben-Bheula (Argyllshire), Alps, Limoges, Norway, Brazil. Large crystals at Titanium Mount (Lincoln county, Georgia). Used in porcelain painting, and for tinting artificial teeth. When attenuated crystals are imbedded in rock-crystal they are called Venus' hair.

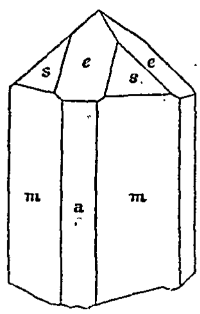


Fig. 286.

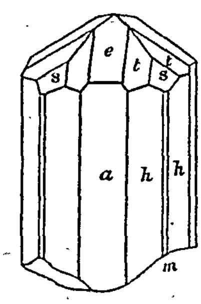


Fig. 287.

109. Manganite, Mn_2O_3, H_2O.

Right prismatic, sometimes hemihedric; ∞P (*M*) 99·40. Crystals prismatic (figs. 298 to 300); vertically striated; also columnar or fibrous. Hemitropes common. Cl. brachydiagonal, perfect; brittle. H. = 3·5 to 4; G. = 4·3 to 4·4. Opaque; metallic lustre. Steel-grey to iron-black; streak brown. B.B. infusible. Sol. in warm h. acid. C.c.: peroxide of manganese 89·9, water 10·1. Grandholm (Aberdeenshire), Cork, Upton Pyne (Exeter), Churchhill (Somerset), Warwickshire, Ihlefeld, Thuringia, Norway, Sweden, Nova Scotia.

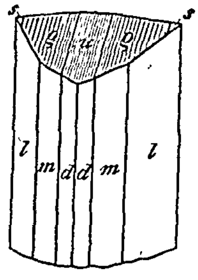


Fig. 298.

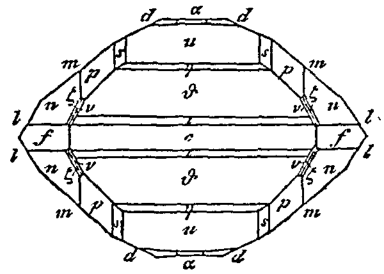


Fig. 299 (sp. 109).

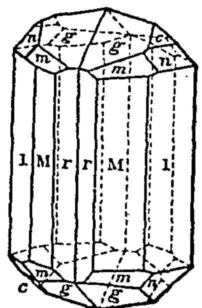


Fig. 300 (sp. 109).

110. Limonite, $2Fe_2O_3+3H_2O$.

Fibrous, botryoidal, and stalactitic, sometimes earthy. H. = 4·5 to 5·5; G. = 3·4 to 3·95. Opaque; lustre silky, glimmering, or dull. Brown, yellowish and blackish brown, often black on surface; streak ochre-yellow. In closed tube yields water and becomes red. B.B. in inner flame becomes magnetic, fusing to a glass. C.c.: peroxide of iron 85·6, water 14·4. Sandlodge (Shetland), Hoy (Orkney), Clifton, Bristol, Cornwall, Harz, Thuringia, Nassau, Styria, Carinthia, Siberia, United States.

111. Xanthosiderite, Fe_2O_3, $2H_2O$.

Fibrous, stellate, also as an ochre. H. = 2·5. Silky or greasy, pitch-like or earthy. In needles, golden-yellow or brown-red; as an ochre, yellow, red, or brown; streak ochre-yellow. B.B. like limonite. C.c.: peroxide of iron 81·6, water 18·4. Hoy (Orkney), Achavarasdale, Kilbride, Wicklow, Ilmenau, Goslar, and Elbingerode in the Harz.

112. Beauxite, $(3Al_2O_3, Fe_2O_3)$, $2H_2O$.

Oolitic, concretionary, disseminated; also earthy and clay-like. G. = 2·55. White, grey, ochre-yellow, brown, and red. C.c.: alumina 50·4, peroxide of iron 26·1, water 23·5. From Beaux (or Baux) near Arles, and elsewhere in France. In grains in compact limestone. Pure varieties used for manufacture of aluminium.

113. Eliasite, $U_2O_3+2H_2O$.

Amorphous masses; resin-like. H. = 3·5 to 4·5; G. = 4 to 5. Reddish brown to black; streak wax-yellow to olive-green. C.c.: 68·5 per cent. sesquioxide of uranium. 10 of water, with impurities. Elias mine (near Joachimsthal).

114. Brucite, MgO,H_2O.

Rhombohedral; R 82° 22′; also foliated and botryoidal columnar. Cl. basal, perfect; sectile; laminæ flexible. H. = 2; G. = 2·3 to 2·4. Translucent, pearly. Colourless. B.B. infusible. Easily soluble in acids. C.c.: 69 magnesia, 31 water. *Nemalite* is a fibrous variety with silky lustre. Swinaness and Quin Gio in Unst, Beresovsk in the Urals, Hoboken, New Jersey, Texas, Pennsylvania.

115. Pyrochroite, MnO, H_2O.

Foliated. H. = 2·5. Pearly, white, but changing through bronze to black. Flesh-red by transmitted light. In matrass becomes verdigris-green, finally black, yielding water. Sol. in h. acid. C.c.: protoxide of manganese 79·8, water 20·2. In veins in magnetite at Paisberg in Sweden.

116. Gibbsite (*Hydrargillite*), Al_2O_3, $3H_2O$.

Hexagonal. C.c.: 65·5 alumina, 34·5 water. The crystals are from Zlatoust in the Urals; stalactites from Richmond in Massachusetts and Villa Rica in Brazil.

117. Limnite, Fe_2O_3, $3H_2O$.

Massive in stalactites, also as a yellow ochre. Like limonite, but pitchy lustre. C.c.: peroxide of iron 74·8, water 25·2. Leadhills, Botallack (Cornwall), Novgorod (Russia).

118. Hydrotalcite, Al_2O_3, $3H_2O+6MgO$, H_2O+6H_2O.

Hexagonal. Cl. basal, foliated, and somewhat fibrous. H. = 2; G. = 2·04. White, pearly. Greasy to the touch. Translucent. C.c.: alumina 16·8, magnesia 39·2, water 44. Zlatoust, Urals; Snarum, Norway; New York.

119. Pyroaurite, Fe_2O_3, $3H_2O+6MgO$, H_2O+6H_2O.

Hexagonal; tables and scaly coatings. Lustre pearly to submetallic. Colour white to gold-yellow. Translucent. B.B. infusible, yields water. Sol. in h. acid. C.c.: peroxide of iron 23·9, magnesia 35·8, water 40·3. Haaf Grunay in Shetland, Långban in Wermland.

120. Gummite, U_2O_3, $3H_2O$.

In rounded lumps, resembling gum. H. = 2·5 to 3; G. = 3·9 to 4·2. Lustre greasy. Reddish yellow to yellowish brown. C.c.: 72 per cent. sesquioxide of uranium water 14·75, with impurities. Johann-Georgenstadt.

121. Psilomelane, (BaO, MnO) MnO_2+3H_2O, MnO_2+3H_2O.

Massive and botryoidal; fracture conchoidal. H. = 5·5 to 6; G. = 4·1 to 4·3. Bluish black. B.B. infusible. About 80 per cent. of oxide of manganese, with baryta, potash, and water. Hoy (Orkney), Leadhills, Cornwall, Devon, Schneeberg, Ilmenau, Vermont in France. *Wad* is similar, but sometimes soft and light. Leadhills, Cornwall, Harz, France.

122. Chalcophanite, $MnOZnO+2MnO_2+2H_2O$.

Hexagonal. R : R 114° 30′. Cl. basal. H. = 2·5; G. = 3·91. Metallic lustre. Blue-black; streak brown, dull. Opaque; flexible. C.c.: manganese binoxide 59·94, protoxide 6·6, zinc oxide 21·7, water 11·6. Sterling Hill (New Jersey).

OXIDES OF NON-METALS.

1. Oxides of Arsenic-Antimony Family (Teroxides).

123. Arsenolite, AsO_3.

Cubic; in octahedra; also botryoidal, stalactitic. H. = 1·5; G. = 3·7. Lustre vitreous. White; streak pale yellow. Translucent. Sublimes in closed tube, condensing in brilliant octahedra. C.c.: arsenic 75·76, oxygen 24·24. Cornwall, Andreasberg, Joachimsthal, Kapnik (Hungary), Nevada, California.

124. Senarmontite, SbO_3.

Cubic; in octahedrons. Cl. octahedral, also massive granular. H. = 2 to 2·5; G. = 5·22 to 5·3. Transparent; adamantine. White or grey. B.B. in inner flame fuses and colours the flame greenish blue. Sol. in h. acid. C.c.: antimony 83·56, oxygen 16·44. Endellion in Cornwall, Constantine in Algeria, Malaczka in Hungary.

125. Valentineite, SbO_3.

Right prismatic; ∞P 137°. Cl. ∞P, perfect. H. = 2·5 to 3; G. = 5·5 to 5·6. Translucent; adamantine to pearly. Yellowish white, brown-grey; streak white. Other properties and composition like senarmontite. Glendinning (Dumfriesshire), Przibram, Bräunsdorf (Saxony), Harz, Hungary, Allemont (Dauphiné), Siberia.

126. Bismite, BiO_3.

Massive, earthy. G. = 4·36. Grey, yellow, green. C.c.: bismuth 89·65, oxygen 10·35. St Agnes (Cornwall), Schneeberg, Siberia.

127. Molybdite, MoO_3.

Right prismatic; ∞P 136° 48′. In capillary crystals, also powdery. H. = 1 to 2; G. = 4·5. Straw-yellow to yellowish white. C.c.: molybdenum 65·71, oxygen 34·29. With molybdenite at many of its localities.

128. Tungstite, WO_3.

Earthy. Soft yellow or yellowish green. Sol. in alkalies. C.c.: tungsten 79·3, oxygen 20·7. Cumberland and Cornwall, Monroe in Connecticut.

129. Cervantite, SbO_3+SbO_5.

Right prismatic. Acicular, generally earthy. H. = 4 to 5; G. = 4·1. Isabel-yellow, reddish white. B.B. on charcoal reduced; unaltered *per se*. Sol. in h. acid. Harehill, Ayrshire; Endellion, &c., Cornwall; Cervantes, Spain; Felsöbanya, Hungary; Mexico; Canada; California.

130. Stibiconite, SbO_4, H_2O.

Massive, powdery. H. = 4 to 5·5; G. = 5·28. Pale yellow. In closed tube yields water. C.c.: antimony 74·9, oxygen 19·6, water 5·5. Goldkronach (Bavaria).

131. Volgerite, SbO_5, $5H_2O$.

Massive and powdery. White. In tube yields water, below redness. C.c.: antimony 58·9, oxygen 19·3, water 21·8. Constantine in Algeria.

132. Zundererz (*Tinder Ore*).

In soft, flexible, tinder-like masses. Colour dark cherry-red to blackish red; lustre glimmering. Two varieties:—one, from Klausthal, contains antimony oxide 33, iron oxide 40, lead 16, sulphur 4; the other, from Andreasberg and Klausthal, seems to be a mixture of jamesonite (82·04 per cent.), mispickel (13·46), and pyrargyrite (4·34).

133. Tellurite.

Yellowish or whitish. Radiated, spherical masses. Gives the reactions of tellurous acid. Facsebaya and Zalathna, Colorado.

134. Tantalic Ochre.

Powdery; brown; vitreous. Pennikoja in Finland.

2. Oxides of Carbon-Silicon Family (Binoxides).

135. Quartz, SiO_2.

Hexagonal; the purest varieties tetartohedral. The primary pyramid P has the middle edge = 103° 34′, and the polar edges =

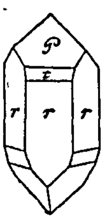
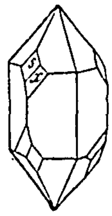
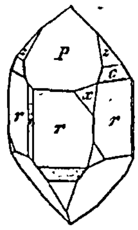
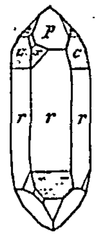
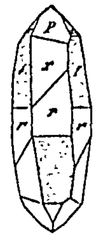






Fig. 301. Fig. 302. Fig. 303. Fig. 304. Fig. 305.

133° 44′, and is often perfect. Very frequently it appears as a rhombohedron R (or ½P), with polar edges = 94° 15′. Crystals often of ∞P, P or ∞P, P, 4P, the forms ∞P and 4P being combined in an oscillatory manner, producing striæ on the face of the prism (figs. 303, 304, 305); also ∞P, P, ¼(2P2), the last face appearing as a rhomb replacing the alternate angles between the two other forms (figs. 307, 308). They are prismatic, or pyramidal, or rhombohedral, when P is divided into R and −R; the latter very often wanting. Many faces plagihedral, as in figs. 302, 306, 309.

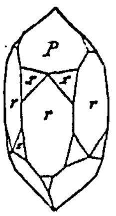
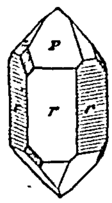
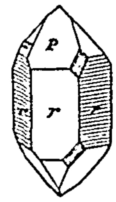




Fig. 306. Fig. 307. Fig. 308.

Twins common, with parallel axes, and either merely in juxtaposition (see fig. 178) or interpenetrating. Crystals often distorted, as in figs. 310 to 313. The crystals occur either single, attached, or imbedded, or in groups and druses. Most frequently granular, massive, fibrous, or columnar; also in pseudomorphs, petrifactions, and other forms. Cl. rhombohedral along R, very imperfect; prismatic along ∞P, still more imperfect; fracture conchoidal, uneven, or splintery. H. = 7; G. = 2·5 to 2·8; 2·65 in the purest varieties. Colourless, but more often white, grey, yellow, brown, red, blue, green, or even black. Lustre vitreous, inclining to resinous; transparent or translucent; when impure almost opaque. B.B. infusible alone; with soda effervesces, and melts into a clear glass. Insoluble in acids, except the hydrofluoric; when pulverized, slightly soluble in solution of potash. C.c.:

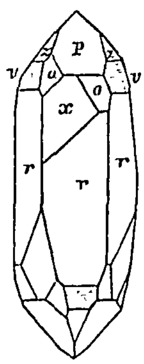


Fig. 309.

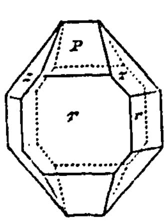
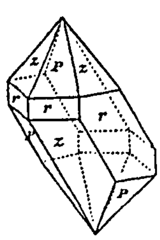
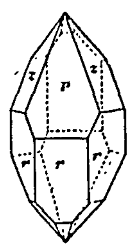
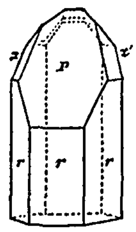





Fig. 310. Fig. 311. Fig. 312. Fig. 313.

48·05 silicon and 51·95 oxygen; but frequently a small amount of the oxides of iron or titanium, of lime, alumina, and other substances.

The following are varieties:—

Rock-crystal: highly transparent and colourless; Dauphiné, Switzerland, Tyrol, Hungary, Madagascar, and Ceylon.

Amethyst: violet-blue (from iron peroxide or manganese), and often marked by zigzag or undulating lines, and the colour disposed in clouds; Siberia, Persia, India, Ceylon, Brazil (white or yellow, named false topaz), Hungary, Ireland (near Cork), and Aberdeenshire. Wine-yellow (*Citrin* and *Gold Topaz*); the brown or *Smoky Quartz* (coloured by a substance containing carbon and nitrogen); and the black or *Morion*, from Siberia, Bohemia, Pennsylvania, and other places. *Cairngorm Stone*, black, brown, or yellow, from Aberdeenshire mountains. The above are valued as ornamental stones; those which follow are less so.

Rose Quartz: red inclining to violet-blue; Clashnaree Hill (Aberdeen), and Rabenstein in Bavaria. *Milk Quartz*: milk-white, and slightly opalescent; Greenland. *Prase*: leek and other shades of green; Saxony and Cedar Mountain in South Africa. *Cat's-eye*, inclosing asbestos: greenish white or grey, olive-green, red, brown, or yellow; Ceylon and Malabar. *Avanturine*, enclosing mica: yellow, red, green, or brown; India, Spain, and Scotland. *Siderite*: indigo or Berlin blue; Golling in Salzburg.

Common Quartz, crystallized or massive, white or grey, also red, brown, &c., is a frequent constituent in many rocks. Some impure varieties are properly rocks, as:—

(1) *Ferruginous Quartz*, or *Iron Flint*: red, yellow, or brown; often associated with iron ores.

(2) *Jasper*: red, yellow, brown, also green, grey, white, and black; alone, or in spots, veins, and bands (*Ribbon* or *Egyptian Jasper*); Urals, Tuscan Apennines, Harz, and many parts of Scotland.

(3) *Lydian Stone*, or *Flinty Slate*: black, grey, or white; has a splintery or conchoidal fracture, breaks into irregular fragments, and passes by many transitions into clay-slate, of which it is often merely an altered portion, as in Scotland; used as a touchstone for gold, and at Elfdal (Sweden) manufactured into ornaments.

(4) *Hornstone* or *Chert*: compact, conchoidal, splintery fracture; translucent on the edges; dirty grey, red, yellow, green, or brown; passes into flinty slate or common quartz; common in the Mountain limestone, Oolite, and Greensand formations; and often contains petrifactions, as shells, corals, and wood.

Other siliceous minerals seem intimate mixtures of quartz and opal, as:—

Flint: greyish white, grey, or greyish black, also yellow, red, or brown; sometimes in clouds, spots, or stripes; semitransparent; lustre dull; fracture flat conchoidal; occurs chiefly in the Chalk formation, as in England, Ireland, Aberdeenshire, France, Germany, and other countries; sometimes in beds or vertical veins, often in irregular lumps or concretions, inclosing petrifactions, as sponges, echinoids, shells, or siliceous *Infusoria*. The colour is partly derived from carbon, or organic matter. Used formerly for gun-flints, and still for the manufacture of glass and pottery; and cut into cameos or other ornaments.

Chalcedony: semitransparent or translucent; white, grey, blue, green, yellow, or brown; stalactitic, reniform, or botryoidal, and in pseudomorphs or petrifactions; Iceland, Faroes, Trevascus in Cornwall, Scotland, Hungary, Bohemia, Oberstein. *Carnelian*: chiefly blood-red, but also yellow, brown, or almost black; India, Arabia, Surinam, and Siberia; also Bohemia, Saxony, and Scotland (Fifeshire). *Plasma*: leek- or grass-green, and waxy lustre; Olympus, Black Forest, India, and China.

Chrysoprase: apple-green; Silesia, and Vermont in North America. *Moss-Agate* and *Heliotrope*: dark green and dendritic (called *Bloodstone* when sprinkled with deep red spots); India, Siberia, Bohemia, Fassa Valley, island of Rum and other parts of Scotland.

136. Tridymite, SiO_2.

Hexagonal; P middle edge 124° 4′, polar edges 127° 35′. Single crystals, very minute hexagonal tables of 0P, ∞P, but with the edges replaced by P and ∞P2, are rare (fig. 314). Mostly twinned

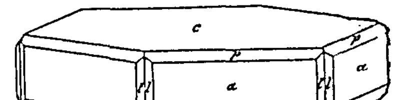


Fig. 314.

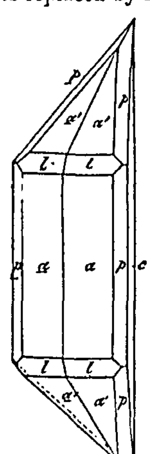


Fig. 315.

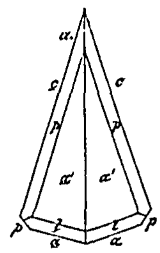


Fig. 316.

in double or (oftener) triple combinations (figs. 315 to 317). Cl. basal, indistinct; fracture conchoidal. H. = 7; G. = 2·282 to 2·326. Colourless and transparent; vitreous, pearly on the base. B.B. like quartz. C.c.: 96 silica, with some alumina, magnesia, and iron peroxide, probably from the matrix. Discovered by Von Rath in the trachyte of San Cristobal, near Pachuca, in Mexico; also in the trachyte of Mont-Dore (Puy-de-Dôme), the Drachenfels, and Hungary. Many opals, treated with solution of potash, leave crystals, as those from Zimapan, Kaschau, Silesia, and the cacholong from Iceland. Where such crystals are abundant, the opal becomes opaque or snow-white. Jenzsch regards these as still another variety of silica.

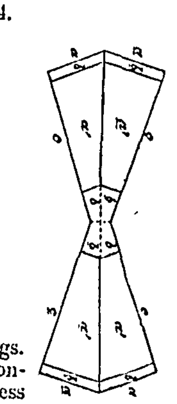


Fig. 317.

137. Opal, $9SiO_2$, H_2O to $3SiO_2$, H_2O.

Amorphous; fracture conchoidal; very brittle. H.=5·5 to 6·5; G.=2 to 2·2. Transparent to opaque; vitreous, inclining to resinous. Colourless, but often white, yellow, red, brown, green, or grey, with a beautiful play of colours. B.B. decrepitates and becomes opaque, but is infusible; in the closed tube yields water; almost wholly soluble in solution of potash. C.c.: silica, with 5 to 13 per cent. water. Most opals are mixtures of various minerals.

The following varieties may be noticed;—(1) *Hyalite, Glassy Opal*, or *Müller's Glass*: transparent, colourless, very glassy; small botryoidal, or incrusting; Kaiserstuhl in the Breisgau, Schemnitz, Silesia, Moravia, Mexico, and other places. (2) *Fire Opal* or *Girasol*: transparent; brilliant vitreous lustre; bright hyacinth-red or yellow; Zimapan in Mexico, and the Faroes. (3) *Noble Opal*, semi-transparent or translucent; resinous, inclining to vitreous; bluish or yellowish white, with brilliant prismatic colours; most show double refraction and are binaxal; in irregular masses or veins near Eperies in Hungary; Australia. (4) *Common Opal*: semitransparent, vitreous; white, yellow, green, red, or brown; Hungary, also Faroes, Iceland, the Giant's Causeway, and the Western Isles of Scotland. (5) *Semi-opal*: duller and less pellucid; *Wood Opal* or *Lithoxylon*: with the form and texture of wood distinctly seen; Hungary, Bohemia, and other countries. (6) *Menilite*: compact, reniform; opaque and brown or bluish grey; Menilmontant, near Paris. (7) *Opal Jasper*: blood-red, brown, or yellow. (8) *Cacholong*: opaque, dull, glimmering, or pearly, and yellowish or rarely reddish white; in veins or reniform and incrusting; Faroes, Iceland, the Giant's Causeway. One variety is named *Hydrophane*, from imbibing water, and becoming translucent. (9) *Siliceous Sinter*: deposited from the Geyser and other hot springs; and *Pearl Sinter*: incrusting volcanic tufa at Santa Fiora in Tuscany (*Fiorite*), and in Auvergne.

138. Zircon, ZrO_2, SiO_2.

Pyramidal; P 84° 20′. Crystals, ∞P, P; often with 3P3; also ∞P∞, P; or ∞P∞ (*s*), ∞P (*l*), P (*P*), 3P3 (*x*), P∞ (*t*), 4P4 (*y*), 5P5 (*z*), (fig. 318, also 86, 87, 585). Chiefly prismatic or pyramidal, and in rounded grains. Transparent to opaque; vitreous, often adamantine. Rarely white, generally grey, yellow, green, or frequently red and brown. B.B. loses its colour, but is infusible. Not affected by any acid except concentrated s. acid, after long digestion. C.c.: 66·3 zirconia and 33·7 silica, with 0 to 2 iron peroxide as colouring matter. Miask, Arendal, Sweden, Belgium (at Nil-St-Vincent), Carinthia, Tyrol, Ceylon, and North America; in Scotland, Scalpay in Harris (fig. 319), Lewis (*Hyacinth*), Sutherland, Ross. The colourless varieties are sold for diamonds. The more brilliantly coloured are named hyacinths, and are valuable gems.

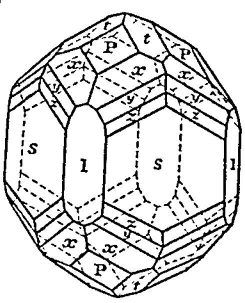


Fig. 318.

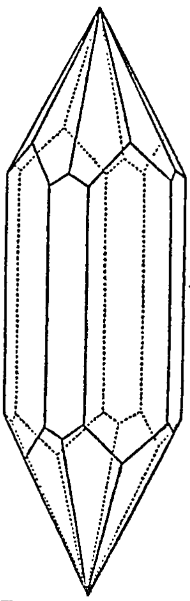


Fig. 319 (sp. 138).

SULPHIDES, SELENIDES, TELLURIDES, &c.

139. Pyrite, FeS_2.

Cubic; semitesseral dominant (figs. 320 to 323, also 67 to 77, and 26 to 34). Pentagonal-dodecahedron in excess; or striæ, produced by oscillation of it with faces of the cube, visible. Often distorted, as in the cubo-octahedral twin (fig. 323). Sometimes massive and in pseudomorphs. Cl. cubic or octahedral, difficult; brittle. H.=6 to 6·5; G.=4·9 to 5·2. Brass-yellow, often somewhat gold-yellow; streak brownish black, when broken emits smell of sulphur. In closed tube sulphur sublimes. B.B. on charcoal burns with blue flame, and odour of sulphurous acid. In inner flame fuses to magnetic bead. Sol. in n. acid, with deposition of sulphur. C.c.: iron 46·7, sulphur 53·3; often contains gold in visible grains, when broken. Common to rocks of all ages. Tomnadashin, Birnam, Scotland; Cornwall, England; Elba and Traversella; Peru; Rossie, Middletown, and Schoharie in U.S. Auriferous pyrites, Berezoff (Siberia), Adelfors (Sweden), Mexico. Used to be cut in facets and set as an ornament, under the name of marcasites; also for striking fire in the old firelocks, whence the name of firestone; now used for manufacture of sulphuric acid.

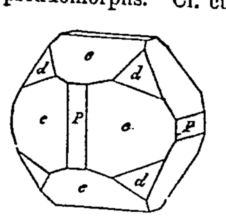


Fig. 320.

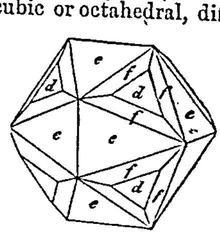


Fig. 321.

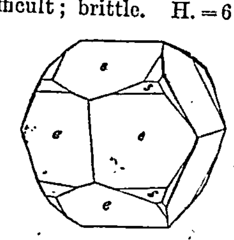


Fig. 322.

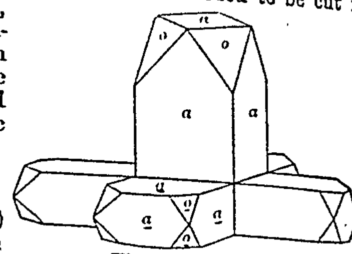


Fig. 323 (sp. 139).

140. Marcasite, FeS_2.

Right prismatic; ∞P (*M*) 106° 5′. Crystals tabular, thin prismatic, or pyramidal. Twins very frequent, also cockscomb-like groups, or spherical and stalactitic. Cl. ∞P; fracture uneven; brittle. G.=4·65 to 4·9. Greyish bronze-yellow to greenish grey, often with brown crust; streak greenish grey or brownish black. B.B., &c., like pyrite. Very prone to decomposition, being changed into green vitriol, which may be detected by the tongue. *Spear Pyrites* are twins like fig. 325; Littmitz, Przibram. *Hepatic Pyrites* or *Leberkies*, liver-brown, generally decomposing; Harz, Saxony, Sweden. *Cockscomb Pyrites*; Derbyshire and the Harz. *Kyrosite* contains arsenic.

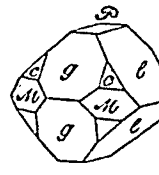


Fig. 324.

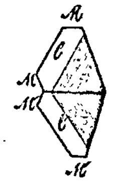


Fig. 325.

141. Mispickel, FeS_2+FeAs.

Right prismatic; ∞P (*M*) 111° 12′ (fig. 326). Twins common; also massive or columnar. Cl. ∞P; fracture uneven; brittle. H.=5·5 to 6; G.=6 to 6·2. Silver-white to steel-grey; streak black. In closed tube yields first a red then a brown sublimate, lastly metallic arsenic. B.B. on charcoal fuses to a black magnetic globule. Sol. in n. acid, with separation of arsenious acid and sulphur. C.c.: 34·3 iron, 46·1 arsenic, 19·6 sulphur; sometimes silver or gold, or 5 to 9 of cobalt. Cornwall, Freiberg, Zinnwald, Sweden, Franconia, America.

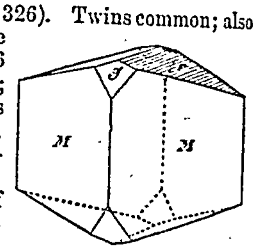


Fig. 326.

142. Leucopyrite, FeAs.

Right prismatic; ∞P (*d*) 122° 26′; P̄∞ (*o*) 51° 20′. Crystals like fig. 327; generally massive or columnar. Cl. basal; fracture uneven; brittle. H.=5 to 5·5; G.=7 to 7·4. Silver-white with darker tarnish; streak greyish black. B.B. emits strong smell of arsenic, and fuses to a black magnetic globule. C.c.: iron 27·2, arsenic 72·8; sometimes iron 32·2 and arsenic 66·8; always some sulphur, and often nickel and cobalt. Fossum in Norway, Andreasberg, Styria, and Silesia. *Spathiopyrite*, from Bieber in Hesse, seems a variety.

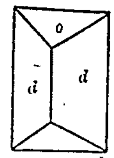


Fig. 327.

143. Cobaltite, CoS_2+CoAs.

Cubic and hemihedral; sometimes massive (figs. 67, 74). Cl. cubic, perfect; brittle. H.=5·5; G.=6 to 6·3. Brilliant lustre. Pinkish silver-white; tarnishes yellow or grey; streak greyish black. B.B. with borax blue glass; evolves smell of arsenic. C.c.: cobalt 35·9, arsenic 44·9, sulphur 19·2. St Just in Cornwall, Tunaberg in Sweden, Skutterud in Norway, Querbach in Silesia.

144. Glaucodote, (Co, Fe)S_2+(Co, Fe)As_2.

Right prismatic; ∞P 112° 36′. Cl. basal, perfect. H.=5; G.=6. Lustre metallic. Greyish white; streak black. C.c.: cobalt 24·7, iron 11·9, arsenic 43·2, sulphur 20·2. Huasco in Chili.

145. Smaltine, (Co, Fe, Ni) As_2.

Cubic; generally like fig. 27; also reticulated and granular compact. Cl. octahedral; fracture uneven; brittle. H.=5·5; G.=6·4 to 7·3. Tin-white to steel-grey, with dark or iridescent tarnish; streak greyish black. Evolves odour of arsenic, when broken or heated. C.c.: 71·4 arsenic, 28·6 cobalt; sometimes 3 to 19 iron, and 1 to 12 nickel, or 4 bismuth. Dolcoath and Redruth in Cornwall, Schneeberg, Annaberg, Tunaberg, Allemont, Chatham in Connecticut.

146. Chloantite (*White Nickel*), NiAs.

Cubic; generally fine granular or compact; fracture uneven; brittle. H.=5·5; G.=6·4 to 6·6. Tin-white, rapidly tarnishing black. In the closed tube yields a sublimate of arsenic, and becomes copper-red. Gives odour of arsenic when broken. B.B. fuses with much smoke, becomes coated with crystals of arsenious acid, and leaves a brittle grain of metal. C.c.: 28·2 nickel, 71·8 arsenic, but often with cobalt. Schneeberg, Riechelsdorf, Allemont, Chatham in Connecticut.

147. GERSDORFFITE, NiS_2+NiAs_2.

Cubic (figs. 74, 30, 26). Cl. cubic, generally granular. H. = 5·5; G. = 6·67. Lustre metallic. Silver-white to steel-grey, decrepitates in closed tube. B.B. fuses to a black slag; partially sol. in n. acid. C.c.: 35·2 nickel, 45·4 arsenic, and 19·4 sulphur; sometimes with cobalt. Craignuir, near Loch Fyne, with 23 nickel and 6 cobalt. The Harz, Sweden, Spain, and Brazil.

148. ULLMANNITE, $NiSb+NiS_2$.

Cubic (figs. 31, 29, 27); often tetrahedral, and in twins as in figs. 328, 329. Cl. cubic, perfect; fracture uneven. H. = 5 to 5·5; G. = 6·2 to 6·5. Lead-grey to tin-white, often with iridescent

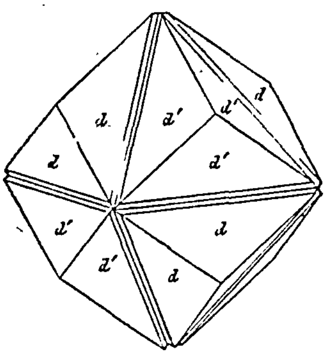


Fig. 328.

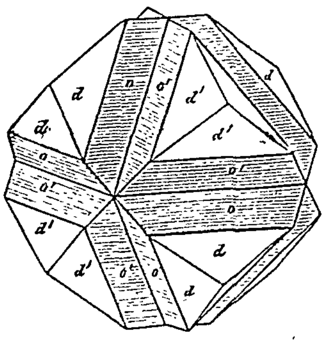


Fig. 329.

tarnish. B.B. fuses with dense fumes. Sol. in n. acid. C.c.: 27·4 nickel, 57·5 antimony, and 15·1 sulphur. Westerwald, Siegen, Harzgerode, Lölling (Carinthia), Lobenstein, and Bleiberg.

149. RAMMELSBERGITE, NiAs.

Right prismatic; ∞P 123° to 124°. Chiefly massive, or in radiating and botryoidal aggregates. H. = 5; G. = 7·2. Colour tin-white. Schneeberg, Reichelsdorf, and Wittichen in Baden.

150. HAUERITE, MnS_2.

Cubic (figs. 30, 30–26, 30–33–37). Crystals single or in spherical groups. Cl. cubic, perfect; H. = 4; G. = 3·46. Reddish brown to brownish black; streak brownish red. In closed tube yields sulphur, and leaves a green mass, which is sol. in h. acid. C.c.: 46 manganese and 54 sulphur. Kalinka in Hungary.

151. PYRRHOTITE (*Magnetic Pyrites*), Fe_7S_8.

Hexagonal; P 126° 48′. Crystals rare, sometimes hemihedral on $z\frac{1}{4}$, commonly massive or granular. Cl. ∞P, imperfect; brittle. H. = 3·5 to 4·5; G. = 4·5 to 4·6. Colour bronze-yellow with pinchbeck-brown tarnish; streak greyish black. More or less magnetic. C.c.:

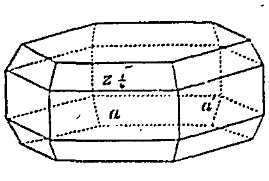


Fig. 330.

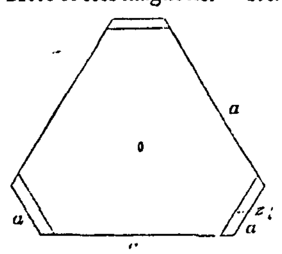


Fig. 331.

63·65 iron and 36·35 sulphur; sometimes with nickel. Common in primary limestones and diorites of Scotland. Crystallized in above forms at Askaig, on Loch Shin, Sutherland; Carnarvon, Cornwall, Fahlun, Bodenmais, Andreasberg. Distinguished by its colour and its solubility in h. acid.

152. LINNÆITE, $2(Co, Cu)S+CoS_2$.

Cubic (figs. 29, 30); often twinned; twin face O; also massive. Cl. cubic; brittle. H. = 5·5; G. = 4·9 to 5. Silver-white, with a yellow tarnish; streak blackish grey. B.B. fuses to a grey magnetic globule, which is bronze-yellow when broken. C.c.: cobalt 43·2, copper 14·4, iron 3·5, sulphur 38·5. Bastnaes (Sweden).

153. SIEGENITE, $CoS+Ni_2S_3$ (?).

Cubic; generally in crystals like fig. 29; also massive. Colour silver-white, inclining to pink. Other features like linnæite. C.c.: cobalt 40·8, nickel 14·6, sulphur 43·1. Müsen near Siegen, Maryland, and Missouri. The American mineral has 30·5 of nickel.

154. POLYDYMITE, Ni_4S_5.

Cubic; in minute octahedral crystals and flattened twins. Cl. cubic. H. = 4·5; G. = 4·81. C.c.: 39·45 nickel, 40·55 sulphur, but generally with 4 of iron. Westphalia. *Saynite* or *grunauite* seems to be a bismuthic and cobaltic variety; it is from Grunau in Sayn-Altenkirchen.

155. BEYRICHITE, $3NiS+2NiS_2$.

H. = 3 to 3·5; G. = 4·7. C.c.: 54·23 nickel, 2·79 iron, 42·86 sulphur. From the Westerwald.

156. HORBACHITE, $4Fe_2S_3+Ni_2S_3$.

Crystalline masses. H. = 4·5; G. = 4·43 to 4·7. Colour pinchbeck-brown; streak black. C.c.: nickel 11·98, iron 41·96, sulphur 45·87. Horbach in the Black Forest.

157. SKUTTERUDITE, $CoAs_3$.

Cubic (figs. 30, 26 with 33, 40) and granular. Cl. cubic; fracture conchoidal; brittle. H. = 6; G. = 6·74 to 6·84. Tin-white to lead-grey. Lustre brilliant. In closed tube gives sublimate of metallic arsenic, otherwise like smaltine. C.c.: 79 arsenic, 21 cobalt. Skutterud, near Modum in Norway.

158. GALENA, PbS.

Cubic; crystals chiefly cube, octahedron, and rhombic dodecahedron; rarely 2O and 2O2. Also massive and granular, compact, or laminar, and in pseudomorphs of pyromorphite and other minerals. Cl. cubic, very perfect; fracture scarcely observable; sectile. H. = 2·5; G. = 7·2 to 7·6. Lead-grey, with darker or rarely iridescent tarnish; streak greyish black. B.B. decrepitates, fuses, and leaves a globule of lead. Sol. in n. acid. C.c.: 86·7 lead, and 13·3 sulphur; but usually contains a little silver, ranging from 1 to 3 or 5 parts in 10,000; rarely 1 per cent. or more. Some contain copper, zinc, or antimony, others selenium, and others (the "supersulphuret") probably free sulphur (2 to 8 per cent.). Most common ore of lead in many countries. Leadhills, Pentland Hills, Linlithgow, Inverkeithing, Monaltrie, Tyndrum, Strontian, Islay, Orkney, Cornwall, Derbyshire (Castletown), Cumberland (Alston Moor), Durham (Allenhead), Wales, Isle of Man.

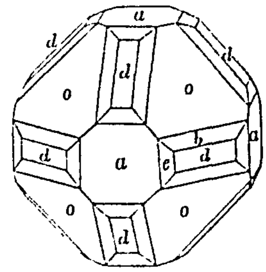


Fig. 332.

159. CUPROPLUMBITE, $2PbS+Cu_2S$.

Cubic. H. = 2·5; G. = 6·4. Bluish grey. Chili.

160. BEEGERITE, $6PbS+Bi_2S_3$.

Cubic. G. = 7·27. Cl. cubic. Light to dark grey. Lustre brilliant. C.c.: sulphur 15, bismuth 20·6, lead 64·2, with copper 1·7. Grant (Park county, Colorado).

161. CLAUSTHALITE, PbSe.

Cubic; but massive granular. H. = 2·5 to 3; G. = 8·2 to 8·8. Lead-grey; streak grey. B.B. fuses, smells of selenium, colours the flame blue, stains the support red, yellow, and white, and volatilizes, except a small residue, without fusing. C.c.: 72·7 lead, 27·3 selenium; but sometimes 11·7 of silver. Zorge, Lerbach, and Clausthal in the Harz. *Tilkerodite*, or *Selen-Cobalt-Blei*, containing 3 per cent. of cobalt, from Tilkerode, is a variety.

162. ZORGITE.

Massive granular; like clausthalite, but inclining to reddish, and often tarnished. There are four varieties. (*a*) *Selen-Blei-Kupfer*: G. = 7·4 to 7·5; 5PbSe + CuSe; with 4 copper, 65 lead, 30 selenium. (*b*) The same, but with G. = 5·6; 4Pb, 4Cu, 7Se; with 15·8 copper, 48·4 lead, and 35 selenium. (*c*) *Selen-Kupfer-Blei*: with G. = 7; 2PbSe + CuSe; with 8 copper, 57 lead, and 32 selenium. (*d*) 2PbSe + 9CuSe; with 46·64 copper, 16·58 lead, and 36·59 selenium. From Tilkerode and Zorge in the Harz, and near Gabel in Thuringia.

163. ALTAITE, PbTe.

Cubic and granular; fracture uneven; sectile. H. = 3 to 3·5; G. = 8·1 to 8·2. Tin-white to yellow, with yellow tarnish. B.B. colours the flame blue, fusing to a globule, which almost wholly volatilizes. C.c.: 61·9 lead and 38·1 tellurium. Zavodinski in the Altai, California, Colorado, and Chili.

164. REDRUTHITE (*Copper Glance*), Cu_2S.

Right prismatic. ∞P (*o*) 119° 35′; P (*P*) middle edge 125° 22′; $\frac{1}{3}\breve{P}$ (*a*) middle edge 65° 40′; $2\breve{P}\infty$ (*d*) middle edge 125° 40′; $\frac{2}{3}\breve{P}\infty$ (*e*) middle edge 65° 48′. Crystals 0P (*s*), ∞P (*o*), $\infty\breve{P}\infty$ (*p*) (figs. 333,

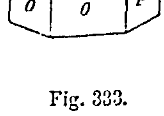


Fig. 333.

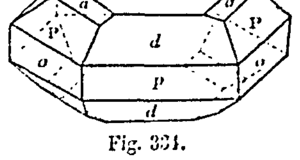


Fig. 334.

334); with hexagonal aspect; also twins; and massive. Cl. ∞P, imperfect; fracture conchoidal or uneven; sectile. H. = 2·5 to 3;

G. = 5·5 to 5·8. Rather dull; brighter on the streak. Blackish lead-grey, with a blue or other tarnish. B.B. colours the flame blue; on charcoal in the oxygen flame sputters, and fuses easily; in the red. flame becomes solid. With soda gives a grain of copper. Green solution in n. acid, leaving sulphur. C.c.: 79·8 copper, 20·2 sulphur. Fassnet Burn (Haddingtonshire), Ayrshire, Fair Island, near Redruth and Land's End in Cornwall, Saxony, Silesia, Norway, the Banat, Siberia, and the United States. Important copper ore.

165. STROMEYERITE, $Cu_2S + AgS$.

Right prismatic; isomorphous with redruthite. Crystals rare; usually massive; fracture flat, very sectile. H. = 2·5; G. = 6·2 to 6·3. Bright. Blackish lead-grey. C.c.: 53·1 silver, 31·2 copper, and 15·7 sulphur, but often indeterminate proportions of silver (3 to 53) and copper (30 to 75). Schlangenberg in Siberia, Rudelstadt in Silesia, and Catemo in Chili.

166. BERZELINITE, Cu_2Se.

Crystalline, in thin dendritic crusts, and imbedded in calcite. Silver-white with a black tarnish; streak shining. In open tube gives a red sublimate of selenium, with white crystals of selenious acid. B.B. on charcoal fuses to a grey, slightly malleable bead, giving odour of selenious acid; with soda a grain of copper. C.c.: 61·5 copper and 38·5 selenium. Skrikerum in Småland, Lerbach in the Harz.

167. CROOKESITE, $(CuTl)_2Se$.

In crystalline grains the size of peas. H. = 2·5 to 3; G. = 6 9. Brittle. Lead-grey. Metallic. B.B. colours the flame intense green. C.c.: 45·76 copper, 3·71 silver, 17·25 thallium, 33·27 selenium. From Skrikerum.

168. EUKAIRITE, $Cu_2Se + AgSe$.

Massive and granular crystalline. Cuts with knife. Lead-grey; streak shining. B.B. fuses to a brittle metallic grain. C.c.: 43·1 silver, 25·3 copper, and 31·6 selenium. Skrikerum, Atacama, Chili.

169. ARGENTITE, Ag_2S.

Cubic. ∞O∞; O; ∞O; and 2O2 (figs. 29, 56). Crystals generally misshapen, with uneven or curved faces; in druses, or linear groups; also arborescent, capillary, or in crusts. Cl. indistinct; fracture hackly; malleable and flexible. H. = 2 to 2·5; G. = 7 to 7·4. Rarely brilliant, more so on the streak. Blackish lead-grey, often with a black, brown, or rarely iridescent tarnish. B.B. on charcoal fuses, intumesces greatly, and leaves a grain of silver. Sol. in con. n. acid. C.c.: 87 silver and 13 sulphur. Huel Duchy, Dolcoath, Herland, and near Callington in Cornwall; Alva in Stirlingshire; Freiberg, Marienberg, Annaberg, Schneeberg, Johann-Georgenstadt, Joachimsthal, Schemnitz and Kremnitz, Kongsberg. Common ore at Guanajuato and Zacatecas in Mexico, in Peru, and at Blagodat in Siberia.

170. ACANTHITE, AgS.

Right prismatic. H. = 2·5; G. = 7·33. Iron-black. C.c. like argentite, thus dimorphous. Freiberg and Clausthal, on argentite; also at Copiapo.

171. JALPAITE, $3AgS + Cu_2S$.

Cubic; form O. Cl. cubic; malleable. H. = 2·5; G. = 6·88. Dark-grey. Metallic lustre. C.c.: silver 71·78, copper 14·04, sulphur 14·2. Jalpa in Mexico.

172. LAUTITE (CuAg) As.S.

Granular. Iron-black. H. = 3; G. = 4·96. C.c.: copper 28·3, silver 12, arsenic 41·8, sulphur 17·86. Lauta, near Marienberg.

173. NAUMANNITE, AgSe.

In thin plates and granular. Cl. hexahedral, perfect. Malleable. H. = 2·5; G. = 8. Iron-black. Splendent. C.c.: 73 silver and 27 selenium, with 4·91 lead. Tilkerode.

174. HESSITE, AgTe.

Cubic or anorthic (?); massive and granular. Slightly malleable. H. = 2·5 to 3; G. = 8·1 to 8·45. Blackish lead-grey to steel-grey. B.B. on charcoal fumes, fuses to a black grain with white spots, and leaves a brittle grain of silver. C.c.: 62·8 silver and 37·2 tellurium. Zavodinski (Altai), Nagyag, Rezbanya, California, and Chili.

175. PETZITE, 2AgTe + AuTe.

Like hessite. Two varieties:—(a) with G. = 8·72, containing 18 per cent. of gold, from Nagyag; (b) with G. = 9 to 9·4, and 24 to 26 of gold. Calaveras and Tuolumne in California, Colorado.

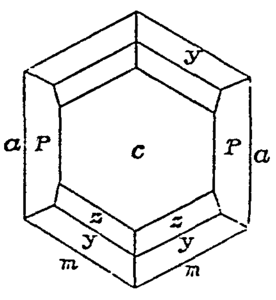


Fig. 335 (sp. 176).

176. DISCRASITE, Ag_2Sb; Ag_3Sb; and Ag_6Sb.

Right prismatic; P with polar edges 132° 42′ and 92°; ∞P 120° nearly (figs. 335, 336). Crystals short prismatic, or thick tabular, and vertically striated (fig. 335); twins united by a face of ∞P; often in stellar groups (fig. 336); also massive or granular. Cl. basal and P̆∞, distinct; ∞P imperfect; rather brittle, and slightly malleable. H. = 3·5; G. = 9·4 to 9·8. Silver-white to tin-white, with a yellow or blackish tarnish. B.B. fuses easily, fumes staining the charcoal white, and leaves a grain of silver. Sol. in n. acid. C.c.: 64 to 84 silver, and 36 to 16 antimony. Andreasberg, Allemont in Dauphiné, Spain, and Arqueras in Coquimbo (Chili). A valuable ore of silver. A variety from Chili contains 94·2 silver and 5·8 antimony, and is $Ag_{18}Sb$.


Fig. 336.

177. BLENDE, ZnS.

Cubic and tetrahedral (figs. 152, 153, 337). Twins remarkably common, united by a face of O, and several times repeated; frequently massive and granular. Cl. ∞O, perfect; very brittle. H. = 3·5 to 4; G. = 3·9 to 4·2. Semitransparent to opaque; adamantine and resinous. Brown or black, also red, yellow, and green, rarely colourless or white. B.B. decrepitates, often violently, but only fuses on very thin edges. Sol. in con. n. acid, leaving sulphur. C.c.: 67 zinc and 33 sulphur; but generally in the darker varieties with 1 to 15 iron, 0 to 3 cadmium. Very abundant. Glen Gairn (bright yellow and highly phosphorescent), Leadhills, Tyndrum, Cornwall, Derbyshire, Cumberland, the Harz, Freiberg, Przibram, Schemnitz, Kapnik, North America, Peru. Used for producing zinc vitriol and sulphur, and as an ore of zinc. Lithium, indium, thallium, and gallium have all been found in blende.

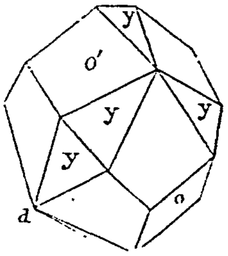


Fig. 337.

178. WURTZITE, 6ZnS + FeS.

Hexagonal; ∞P, P, with well-marked horizontal striæ. Cl. basal, and prismatic. H. = 3·5 to 4; G. = 3·9 to 4·1. Brownish black; streak light brown. C.c.: like blende, which is thus dimorphous. Oruro in Bolivia, and Przibram (radiated and cadmiferous).

179. GREENOCKITE, CdS.

Hexagonal, and generally hemimorphic. P 86° 21′; 2P 123° 54′. Crystals 2P, 0P, ∞P, P; or P, 2P, ∞P; attached singly. Cl. ∞P, imperfect; basal perfect. H. = 3 to 3·5; G. = 4·8 to 4·9. Translucent; brilliant resinous, or adamantine. Honey- or orange-yellow, rarely brown; streak yellow. B.B. decrepitates, and becomes carmine-red, but again yellow when cold; fused with soda forms a reddish brown coating on charcoal. Sol. in h. acid. C.c.: 77·6 cadmium, and 22·4 sulphur. Bishopton in Renfrewshire, Przibram, and Friedensville in Pennsylvania.

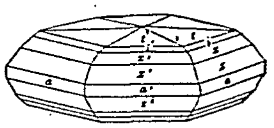


Fig. 338.

180. ALABANDINE, MnS.

Cubic; O and ∞O∞; usually massive and granular. Cl. hexahedral, perfect; fracture uneven; rather brittle. H. = 3·5 to 4; G. = 3·9 to 4. Opaque; semi-metallic. Iron-black to dark steel-grey, brownish black tarnish; streak dark green. B.B. fuses on thin edges to a brown slag. Sol. in h. acid. C.c.: 63 manganese and 37 sulphur. Nagyag, Kapnik, Alabanda in Caria, Mexico, and Brazil.

181. MILLERITE, NiS.

Hexagonal rhombohedral; R 144° 8′; in fine acicular prisms of ∞P2, R. Brittle. H. = 3·5; G. = 4·6 (or 5·26 to 5·65). Brass- or bronze-yellow, with a grey or iridescent tarnish. B.B. fuses easily to a blackish metallic globule, which boils and sputters. In nitro-hydrochloric acid forms a green solution. C.c.: 64·4 nickel and 35·6 sulphur. Morven (Argyllshire), Chapel (Fife), Ayrshire, near St Austell in Cornwall, at Merthyr-Tydvil, Johann-Georgenstadt, Joachimsthal, Przibram, Camsdorf, Riechelsdorf, Pennsylvania.

182. PENTLANDITE (*Eisennickelkies*), 2FeS + NiS.

Cubic; massive and granular; fracture uneven; brittle. H. = 3·5 to 4; G. = 4·6. Light pinchbeck-brown, with darker streak. Not magnetic. B.B. acts in general like pyrrhotite; the roasted powder forms with borax in the red. flame a black opaque glass. C.c.: 36 sulphur, 42 iron, and 22 nickel; but mixed with pyrrhotite and chalcopyrite. Lillehammer in southern Norway. *Inverarite*, 5FeS + NiS, with 11 of nickel, from near Inveraray, is a variety.

183. NICKELITE (*Copper Nickel*), NiAs.

Hexagonal; P 86° 50′. Crystals ∞P, 0P; rare. Arborescent, reniform, and massive; fracture conchoidal and uneven; brittle. H. = 5·5; G. = 7·5 to 7·7. Light copper-red, with a blackish tarnish. It forms no sublimate in the closed tube. B.B. fuses with strong

fumes to a white, brittle, metallic globule. C.c.: 43·6 nickel and 56·4 arsenic. Hilderston in Linlithgow, Pibble in Kirkcudbright, Leadhills, Pengelly and Huel Chance in Cornwall, Freiberg, Schneeberg, Joachimsthal, Sangerhausen, Andreasberg, Chatham in Connecticut. Used as an ore of nickel.

184. BREITHAUPTITE (*Antimonial Nickel*), NiSb.

Hexagonal; P 86° 56′. Crystals, thin striated hexagonal tables of 0P, ∞P. H.=5; G.=7·5 to 7·6. Brilliant. Light copper-red, generally with violet tarnish. B.B. fumes, but fuses with great difficulty. C.c.: 32·2 nickel and 67·8 antimony. Andreasberg.

185. STANNITE (*Tin Pyrites*), 2CuS, SnS_2+2(FeS, ZnS)+SnS_2.

Cubic; in cubes very rare, generally massive and granular. Cl. hexahedral, imperfect; fracture uneven or small conchoidal; brittle. H.=4; G.=4·3 to 4·5. Steel-grey; streak black. C.c.: 26 to 32 tin, 24 to 30 copper, 5 to 12 iron, 2 to 10 zinc, and 30 sulphur. Huel Rock near St Agnes, St Michael's Mount, and Carnbrea in Cornwall; Zinnwald. Bell-metal ore.

186. STERNBERGITE, (AgS+2FeS)FeS_3.

Right prismatic; P middle edge 118°. Crystals usually thin tabular; in twins, or in fan-like and spheroidal groups. Cl. basal, perfect; sectile, and flexible in thin laminæ. H.=1 to 1·5; G.=4·2 to 4·25. Dark pinchbeck-brown, often a violet-blue tarnish; streak black. C.c.: 34·2 silver, 35·4 iron, and 30·4 sulphur. Joachimsthal, Schneeberg, and Johann-Georgenstadt. *Flexible Sulphuret of Silver*, from Hungary and Freiberg, is identical. *Frieseite*, $Ag_2Fe_5S_8$, in twins (fig. 339), is a variety.

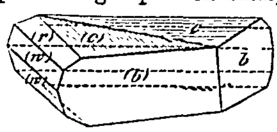


Fig. 339.

187. RITTINGERITE, AgAs.

Oblique prismatic. ∞P 126° 18′; ∞P∞ and 0P. Cl. basal; fracture conchoidal; brittle. H.=2·5 to 3; G.=5·63. C.c.: silver 57·7, the remainder being arsenic, with some selenium. Joachimsthal, Silesia, Felsöbanya in Hungary.

188. COVELLINE, CuS.

Hexagonal. Crystals ∞P, 0P; rare; usually reniform and granular. Cl. basal; sectile. Thin laminæ flexible. H.=1·5 to 2; G.=3·8 to 4·6. Resinous. Indigo-blue; streak black. B.B. burns with blue flame. Sol. in n. acid. C.c.: 66·7 copper, 33·3 sulphur. Cairnbeg in Cornwall, Vesuvius, Leogang (Austria), Chili, Angola, New Zealand, and Victoria.

189. CHALCOPYRITE (*Copper Pyrites*), CuS+FeS.

Pyramidal; and sphenoidal hemihedric; ½P (*P*) with polar edges 71° 20′; ∞P∞. Crystals generally small and deformed; twins very common, like fig. 340. P∞(*b*) 89° 10′, 2P∞(*c*) 126° 11′, 0P (*a*), P (fig. 89). Most commonly compact and disseminated; also botryoidal and reniform. Cl. pyramidal 2P∞; sometimes rather distinct; fracture conchoidal or uneven. H.=3·5 to 4; G.=4·1 to 4·3. Brass-yellow, often with a gold-yellow or iridescent tarnish (peacock copper ore); streak greenish black. B.B. on charcoal becomes darker or black, and on cooling red; fuses easily to a steel-grey globule, which at length becomes magnetic, brittle, and greyish red on the fractured surface; with borax and soda yields a grain of copper; moistened with h. acid, colours the flame blue. C.c. essentially 1 atom copper, 1 atom iron, and 2 atoms sulphur; with 34·5 copper, 30·5 iron, and 35 sulphur. The most abundant ore of copper. In Kirkcudbrightshire and Wigtownshire, Tyndrum in Perthshire, Inverness-shire, Lairg in Sutherland, Shetland, Anglesea (Parys mine), Derbyshire, Staffordshire, Cumberland, Gunnislake (Devonshire), St Austell (Cornwall), Wicklow, Falun, Röraas, Freiberg, Mansfeld, Goslar, Lauterberg, Müsen, Siberia. It is distinguished from pyrite by yielding readily to the knife, by its tarnish, and by forming a green solution in n. acid.

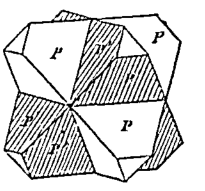


Fig. 340.

190. BORNITE (*Purple Copper*), $3Cu_2S$, Fe_2S_3.

Cubic. Crystals ∞O∞, and ∞O∞, O; but rare, and generally rough or uneven; also twins. Mostly massive. Cl. octahedral; fracture conchoidal; slightly brittle; sectile. H.=3; G.=4·9 to 5·1. Colour between copper-red and pinchbeck-brown, with tarnish at first red or brown, then violet or sky-blue; streak greyish black. B.B. acts like chalcopyrite. Soluble in con. h. acid, leaving sulphur. C.c.: 55·6 copper, 16·4 iron, and 28 sulphur. Crystals near Redruth and St Day in Cornwall; massive at Killarney in Ireland; also Norway, Sweden, Mansfeld, Silesia, Tuscany, and Chili. An ore of copper.

191. CUBAN, CuS, Fe_2S_3.

Cubic. H.=4; G.=4·1. Bronze-yellow; streak bronze-yellow and black. Barracanao in Cuba, Tunaberg and Kafveltorp in Sweden.

192. DOMEYKITE, Cu_6As.

Botryoidal or massive; fracture uneven; brittle. H.=3 to 3·5; G.=7 to 7·5. Tin- or silver-white, inclining to yellow, with an iridescent tarnish. Not affected by h. acid. C.c.: 71·63 copper and 28·37 arsenic. Calabazo in Coquimbo, and Copiapo in Chili. *Condurrite*, massive, seems an impure variety; from Condurrow mine and near Redruth (Cornwall). *Algodonite* from Lake Superior, *Whitneyite* from Mexico, and *Darwinite* (88 copper) are also identical or similar.

193. MELONITE, Ni_2Te_3.

Hexagonal; minute tabular crystals, foliated and granular. Metallic lustre. Reddish white; streak dark grey. C.c.: nickel 21, silver 4·1, tellurium 73·4. Stanislaus and Calaveras (California).

194. SYLVANITE, $AgTe_4$+$AuTe_3$.

Oblique prismatic, C 55° 21′. ∞P 94° 26′; −P∞ 19° 21′; P∞ 62° 43′. Crystals small, short acicular, and often twinned and grouped in rows like letters; sectile, but friable. H.=1·5 to 2; G.=7·99 to 8·33. Steel-grey to silver-white, and pale bronze-yellow. C.c.: 59·6 tellurium, with 0·6 to 8·5 antimony, 26·5 gold (in some 30), and 13·9 silver, with 0·2 to 15 lead. Offenbanya (*Graphic Tellurium*), Nagyag (*Yellow Tellurium*), and California.

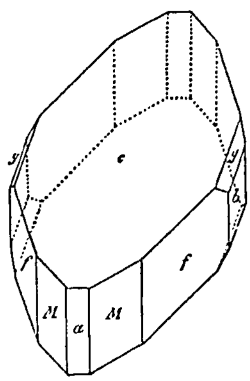


Fig. 341.

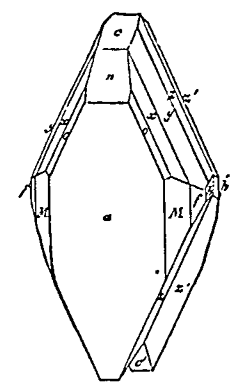


Fig. 342.

195. NAGYAGITE, *Black Tellurium*.

Pyramidal. P 137° 52′; P∞ 122° 50′; and 0P (fig. 343). Crystals tabular, rare; in general in thin plates or foliated. Cl. basal, perfect; sectile; thin laminæ flexible. H.=1 to 1·5; G.=6·85 to 7·2. Splendent. Blackish lead-grey. C.c.: 51 to 63 lead, 6 to 9 gold, 1 copper and silver, 13 to 32 tellurium, 3 to 12 sulphur, and 0 to 4·5 antimony. Nagyag and Offenbanya in Transylvania.

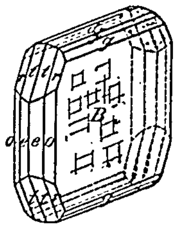


Fig. 343 (sp. 195).

196. MALDONITE, Au_2Bi.

H.=1·5 to 2; G.=8·2 to 9·7. Colour silver-white, with black tarnish. C.c.: gold 64·5, bismuth 35·5. Occurs in granite veins at Maldon in Victoria.

197. CHILENITE, $Ag_{10}Bi$.

Minute plates of metallic lustre. Silver-white, but tarnished red or yellow. Silver 83·9, bismuth 16·1. From the mine San Antonio near Copiapo in Chili.

198. CINNABAR, HgS.

Hexagonal and rhombohedral; R 71° 48′. R (*n*), 0R (*o*), ∞R (*m*). ⅔R (*i*) (fig. 344). Crystals rhombohedral; also granular, compact, and earthy. Cl. ∞R, perfect; fracture uneven and splintery; sectile. H.=2 to 2·5; G.=8 to 8·2. Transparent, with circular polarization. Adamantine. Cochineal-red; streak scarlet. C.c.: 86·2 mercury, 13·8 sulphur. Idria in Carniola, Almaden in Spain, Wolfstein in Bavaria, Saxony, Hungary, Tuscany, China, California, Mexico, Peru. Chief ore of mercury. Also a pigment. *Hepatic Cinnabar* is a bituminous mixture.

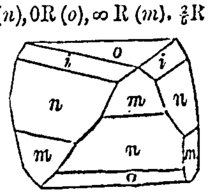


Fig. 344.

199. TIEMANNITE, HgSe.

Fine granular; brittle. H.=2·5; G.=7·1 to 7·4. Brilliant. Dark lead-grey. C.c.: 75 mercury, 25 selenium. Clausthal and Zorge.

200. LERBACHITE, (PbHg)Se.

Granular and massive. G.=7·8 to 7·88. Colour steel-grey to iron-black. Brittle. Lerbach, Tilkerode in the Harz.

201. GUANAJUATITE, Bi_2Se_3.

Massive; granular; foliated and fibrous. H.=2·5 to 3; G.=6·25. Blue-grey; streak grey and shining. Metallic; soft and malleable. C.c.: selenium 34·3, sulphur ·7, bismuth 65. Santa Rosa (Guanajuato, Mexico).

202. Coloradoite, HgTe.

Massive and granular. H. = 3; G. = 8·63. Metallic. Iron-black. Conchoidal fracture. C.c.: 61 mercury, 39 tellurium. Colorado.

203. Molybdenite, MoS_2.

Hexagonal (?). Crystals 0P, ∞P; and 0P, ∞P, P. Generally scaly. Cl. basal, perfect; sectile and flexible. Feels greasy. H. = 1 to 1·5; G. = 4·6 to 4·9. Lead-grey with red tinge; grey streak on paper, greenish on porcelain. B.B. colours flame siskin-green; on charcoal yields sulphurous fumes, and forms a white coating; in warm nitrochloric acid a greenish, and in boiling s. acid a blue solution. C.c.: 59 molybdenum, 41 sulphur. In granular limestones, and in granites in Sutherland, Ross, Aberdeen, Argyll, and Kirkcudbright; Shap in Westmoreland, Caldbeckfell in Cumberland, Arendal, Zinnwald, Mont Blanc, Maine, Connecticut, Yea in Victoria. Used for preparing blue carmine, for colouring porcelain.

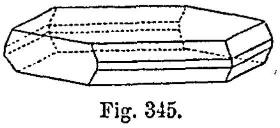


Fig. 345.

204. Laurite, $(RuOs)_2S_3$.

Cubic. Crystals O, $\infty O \infty$; ∞O3, $\infty O \infty$. Cl. octahedral. H. = 7·5; G. = 6·99. Metallic, bright. Dark iron-black. Powder grey. Brittle. C.c.: ruthenium 65·18, osmium 3·03, sulphur 31·79. From platinum grains, in Borneo and Oregon.

205. Realgar, AsS.

Oblique prismatic. ∞P (*M*) 74° 26′; P^c∞ (*n*) 132° 2′, ∞P^{o}2 (*l*) 113° 16′. Crystals (fig. 346) generally prismatic; sometimes massive. Cl. basal, also clinodiagonal; fracture splintery; sectile. H. = 1·5 to 2; G. = 3·4 to 3·6. Transparent to opaque; resinous. Aurora-red; streak orange-yellow. C.c.: arsenic 70, sulphur 30. Nagyag, Felsöbanya, St Gotthard, Vesuvius.

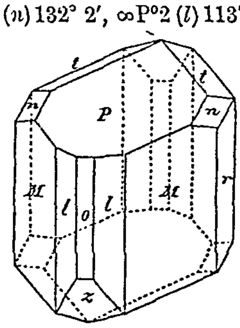


Fig. 346 (sp. 205).

206. Orpiment, As_2S_3.

Right prismatic. ∞P 117° 49′. Frequently foliated. Cl. brachydiagonal; striated vertically; sectile and flexible. H. = 1·5 to 2; G. = 3·4 to 3·5. Semi-transparent; resinous to pearly. Citron-yellow and orange-yellow. C.c.: arsenic 61, sulphur 39. Servia, Kapnik, Andreasberg, Solfatara, Zimapan in Mexico.

207. Dimorphite, As_4S_3.

Right prismatic. H. = 1·5; G. = 3·58. Orange-yellow. Solfatara.

208. Stibnite, Sb_2S_3.

Right prismatic. P polar edges 109° 26′ and 108° 21′; ∞P 90° 54′. Crystals (fig. 347) generally prismatic. Cl. brachydiagonal, perfect; sectile. H. = 2; G. = 4·6 to 4·7. Brilliant lead-grey, often tarnished. C.c.: antimony 71·8, sulphur 28·2. Maisley, Banffshire; Harehill, Ayrshire; Glendinning, Dumfriesshire; Endellion and Padstow, Cornwall; Wolfsberg, Harz; Przibram, Schemnitz, Auvergne, Spain, America, Melbourne. Chief ore of antimony.

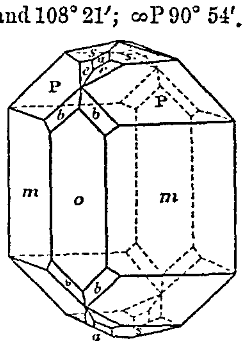


Fig. 347 (sp. 208).

209. Bismuthine, Bi_2S_3.

Right prismatic. ∞P 91° 30′. Crystals prismatic, striated; also granular and foliated. Cl. brachydiagonal; sectile. H. = 2 to 2·5; G. = 6·4 to 6·6. Lead-grey. C.c.: 81·2 bismuth, 18·8 sulphur. Caldbeckfell (Cumberland), Redruth (Cornwall), Riddarhyttan and Bastnaes (Sweden), Altenberg, Haddam (Connecticut), Ballarat (Victoria), Bolivia.

210. Frenzelite, Bi_2Se_3, or $2Bi_2Se_3 + Bi_2S_3$.

Right prismatic; ∞P 90°. Needle crystals, and massive. Cl. brachydiagonal. H. = 2·5 to 3; G. = 6·25. Bluish grey; streak greyish black, shining. Lustre metallic. Malleable. C.c.: bismuth 67·38, selenium 24·13, sulphur 6·6. Guanajuato (Mexico).

SULPHUR SALTS.

211. Guejarite, $Cu_2S + 2Sb_2S_3$.

Right prismatic. ∞P 101° 9′. Cl. brachydiagonal. H. = 3·5; G. = 5·03. Steel-green, with bluish streak. C.c.: copper 15·5, antimony 58·5, sulphur 25. Guejar in Sierra Nevada.

212. Miargyrite, $AgS + SbS_3$.

Oblique prismatic, C 81° 36′. P 90° 53′; −P 59° 59′. Crystals pyramidal, or tabular (fig. 348); massive; sectile. H. = 2 to 2·5; G. = 5·2 to 5·3. Metallic adamantine. Blackish lead-grey to steel grey; streak cherry-red. C.c.: 37 silver, 41 antimony, 22 sulphur. Freiberg, Przibram, Potosi.

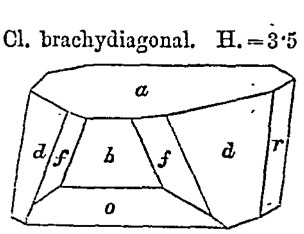


Fig. 348 (sp. 212).

213. Morocochite (*Silber-Wismuth Glanz*), $AgS + BiS_3$.

Massive. Colour grey; streak light green. G. = 6·92. C.c.: silver 28·3, bismuth 54·7, sulphur 17. Morococha in Peru.

214. Sartorite, $PbS + As_2S_3$.

Right prismatic. Crystals slender; ∞P 123° 20′. Cl. 0P. H. = 3; G. = 5·39. C.c.: lead 42·68, arsenic 30·93, sulphur 26·39. Binnenthal in Switzerland.

215. Zinckenite, $PbS + SbS_3$.

Right prismatic. ∞P (*d*) 120° 39′; $\breve{P}\infty$ (*o*) 150° 36′ (fig. 349). Crystals acicular; vertically striated, and twinned 3 or 6. Sectile. H. = 3 to 3·5; G. = 5·3 to 5·35. Steel-grey to lead-grey; with blue tarnish. C.c.: lead 35·9, antimony 42, sulphur 22·1. Wolfsberg.

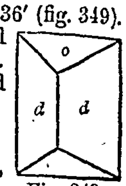


Fig. 349 (sp. 215).

216. Emplectite, $CuS + Bi_2S_3$.

Right prismatic. Tin-white. Saxony, Würtemberg, and Copiapo.

217. Wolfsbergite, $Cu_2S + Sb_2S_3$.

Right prismatic. ∞P 135° 12′; $\infty\breve{P}$2 111°. Crystals tabular; also fine granular. Cl. brachydiagonal, perfect; fracture conchoidal or uneven. H. = 3·5; G. = 4·748. Lead-grey to iron-black, sometimes iridescent; streak black, dull. C.c.: 25·4 copper, 49 antimony, and 25·6 sulphur. Wolfsberg.

218. Berthierite, FeS, SbS_3.

Massive; columnar or fibrous, with indistinct cleavage. H. = 2·3; G. = 4 to 4·3. Dark steel-grey, reddish. Tintagel and Padstow in Cornwall, Auvergne and Anglars (Creuse) in France, Bräunsdorf in Saxony. In France used as an ore of antimony.

219. Plagionite, Pb_4Sb_3.

Oblique prismatic, C 72° 28′. P 134° 30′ and 142° 3′; −2P 120° 49′. Crystals thick, tabular (fig. 350), minute, and in druses. Cl. −2P, perfect; brittle. H. = 2·5; G. = 5·4. Blackish lead-grey. C.c.: 41 lead, 38 antimony, and 21 sulphur. Wolfsberg.

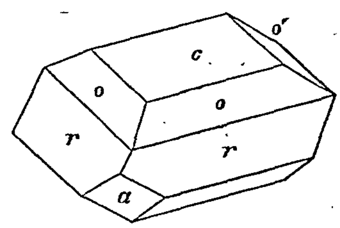


Fig. 350 (sp. 219).

220. Klaprothite, $3Cu_2S + 2Bi_2S_3$.

Right prismatic; long striated crystals; ∞P = 107°. Wittichen, Bulach. *Schirmerite*, from Colorado, $3(Ag_2Pb)S + 2Bi_2S_3$, with G. = 6·74, is similar.

221. Binnite, $3CuS + 2As_2S_3$.

Cubic. Typical forms ∞O, 2O2; O, $\infty O \infty$, 6O6; 4O4, 10O10 3O$\frac{3}{2}$. H. = 4·5; G. = 4·48. Metallic. Black. Binnen.

222. Jamesonite, $3PbS + 2Sb_2S_3$.

Right prismatic; ∞P 101° 20′. Crystals ∞P, $\infty\breve{P}\infty$, long-prismatic, parallel or radiating. Cl. basal perfect, ∞P and brachydiagonal imperfect; sectile. H. = 2 to 2·5; G. = 5·5 to 5·7. Steel-grey to dark lead-grey. B.B. decrepitates, fuses easily, and wholly volatilizes except a small slag. Sol. in warm n. acid. C.c.: 44·5 lead, with 2 to 4 iron, 34·9 antimony, and 20·6 sulphur. Cornwall, Estremadura, Hungary, Siberia, and Brazil.

223. Dufrenoysite, $2PbS + As_2S_3$.

Right prismatic. ∞P 93° 39′. Generally in thick rectangular tables. H. = 3; G. = 5·56. Lead-grey. Brittle. Binnen, St Gotthard.

224. Freieslebenite, $5(Pb, Ag_2)S + 2Sb_2S_3$.

Oblique prismatic, C 87° 46′. ∞P 119° 12′; P^o∞ 31° 41′ (fig. 351) in prisms with curved reed-like faces, and strong vertical striæ. Twins intersecting; also massive. Cl. ∞P, perfect; fracture conchoidal or uneven; rather brittle. H. = 2 to 2·5; G. = 6·2 to 6·4. Steel-grey to dark lead-grey. C.c.: 22·5 silver, 32·4 lead, 26·8 antimony, and 18·3 sulphur. Freiberg (Saxony), Hiendelaencina (Spain).

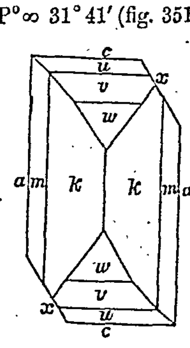


Fig. 351 (sp. 224).

225. Pyrargyrite, $3Ag_2S + Sb_2S_3$.

Hexagonal rhombohedral; R (*P*) 108° 42′; −½R 137° 58′; 0R; −2R (*r*); R3; ∞P2 (*s*); and ∞R (*l*). Crystals prismatic (fig. 352); twins common, of various kinds; also massive, dendritic, or investing. Cl. R, rather perfect; fracture conchoidal to uneven and splintery; sectile. H. = 2 to 2·5. Crimson-red to blackish lead-grey; streak cochineal to cherry-red. Huel Brothers and Huel Duchy in Cornwall, Andreasberg, Freiberg, Johann-Georgenstadt, Annaberg,

Schneeberg, Marienberg, Przibram, Schemnitz and Kremnitz, Kongsberg, Mexico, Nevada, &c.

226. Proustite, $3Ag_2S + As_2S_3$.

Rhombohedral, like pyrargyrite, except R 107° 50′ (fig. 353). G. = 5·5 to 5·6. Semi-transparent to translucent on the edges. Cochineal to crimson-red. C.c.: 65·5 silver, 15·1 arsenic, and 19·4 sulphur. Streak aurora-red. B.B. arsenical odour, and difficultly reduced to metallic silver. At the same localities as pyrargyrite; both are valuable ores of silver. Red orpiment has a lower specific gravity, and yellow streak; cinnabar volatilizes before the blowpipe.

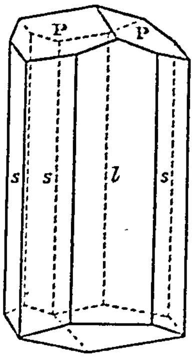


Fig. 352 (sp. 225).

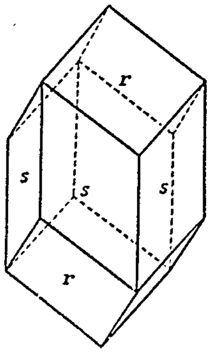


Fig. 353 (sp. 226).

227. Boulangerite, $3PbS + SbS_3$.

Fine granular, columnar, radiating, or fibrous; slightly sectile. H. = 3; G. = 5·8 to 6. Silky, metallic. Blackish lead-grey, with darker streak. B.B. like jamesonite. C.c.: 59 lead, 22·8 antimony, and 18·2 sulphur. Molières in France, Oberlahr (Rhenish Prussia), Lapland, and Siberia. *Plumbostib* or *Embrelhite*, from Nertchinsk, is only a variety.

228. Kobellite, $3PbS$, $Bi_2S_3 + 3PbS$, Sb_2S_3.

Radiated columnar; soft. G. = 6·2 to 6·3. C.c.: 53 lead, 20 bismuth, 10 antimony, and 17 sulphur. Hvena in Nerike (Sweden).

229. Wittichenite (*Cupreous Bismuth*), $3CuS + Bi_2S_3$.

Right prismatic; in tabular crystals like bournonite. Wittichen in the Black Forest.

230. Bournonite $(3CuS + Sb_2S_3) + 2(3PbS + Sb_2S_3)$.

Right prismatic. ∞P (*d*) 93° 40′; $\breve{P}\infty$ (*n*) 96° 13′; $\bar{P}\infty$ (*e*) 92° 34′; 0P (*r*); $\infty\breve{P}\infty$ (*s*); $\infty\bar{P}\infty$ (*k*) (fig. 354). Cl. brachydiagonal, imperfect; fracture uneven to conchoidal; rather brittle. H. = 2·5 to 3; G. = 5·7 to 5·9. Lustre brilliant metallic. Steel-grey. C.c.: 42·4 lead, 13 copper, 25 antimony, and 19·6 sulphur. Redruth and Beeralston; Harz (Neudorf), Bräunsdorf, Kapnik, Servoz; Alais and Pontgibaud in France.

Wölchite from Wölch in Carinthia is only a variety.

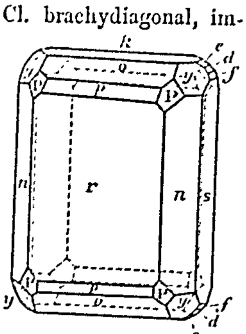


Fig. 354 (sp. 230).

231. Aikinite (*Needle-ore*), $2(3PbS + Bi_2S_3) + 3(CuS + Bi_2S_3)$.

Right prismatic; long thin crystals imbedded in quartz, often bent or broken; rather brittle. H. = 2·5; G. = 6·7 to 6·8. Blackish lead-grey or steel-grey, with a brownish tarnish. C.c.: 36 lead, 11 copper, 36 bismuth, and 17 sulphur. Berezoff (Siberia), Georgia.

232. Stylotyp, $3(CuAgFe)S + Sb_2S_3$.

Right prismatic. 0P 92° 30′. H. = 3; G. = 4·8. Black. Copiapo, Chili.

233. Annivite, $4CuS + (As_2S_3, Sb_2S_3, Bi_2S_3)$.

Massive, similar to the foregoing. From Anniver in Valais. *Studerite* is similar, but with 15·5 of antimony.

234. Julianite, $3Cu_2S + As_2S_3$.

Cubic. G. = 5·12. Metallic. Reddish grey. Rudelstadt in Silesia.

235. Meneghinite, $4PbS + Sb_2S_3$.

Oblique prismatic, C 72° 8′. ∞P 140° 24′; $P^o\infty$ 70°. Crystals small, acicular, chiefly of $\infty P^o\infty$, $\infty P^o\infty$, ∞P; rare; mostly fibrous. H. = 3; G. = 6·4. Bottino in Tuscany, Schwarzenberg in Saxony.

236. Jordanite, $4PbS + As_2S_3$.

Right prismatic; ∞P 123° 29′. Cl. brachydiagonal, perfect. Streak black. G. = 6·38. C.c.: lead 68·9, arsenic 12·5, sulphur 18·6. Binnen and Nagyag.

237. Tetrahedrite (*Fahlerz*), $4Cu_2S + Sb_2S_3$.

Tesseral and tetrahedral. In crystals $\frac{O}{2}$, $-\frac{O}{2}$, ∞O, $\frac{2O2}{2}$ (figs. 355 to 358, also 65, 66, 206). Twins (figs. 164, 207); generally massive. Cl. octahedral; fracture conchoidal; brittle. H. = 3·44; G. = 4·5 to 5·2. Steel-grey to iron-black; streak black (dark red when containing zinc). B.B. on charcoal boils slightly, and fuses to a steel-grey slag, usually magnetic, and with soda gives copper. C.c. essentially Cu_2S in combination with Sb_2S_3. Airthrey near

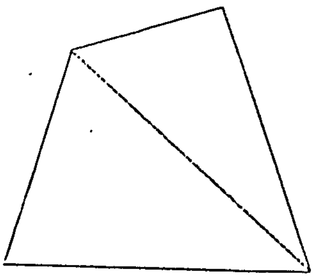


Fig. 355.

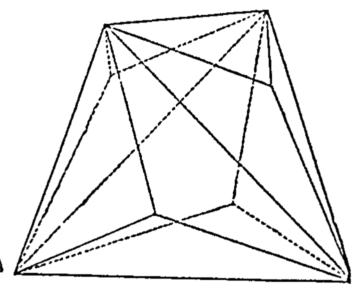


Fig. 356.

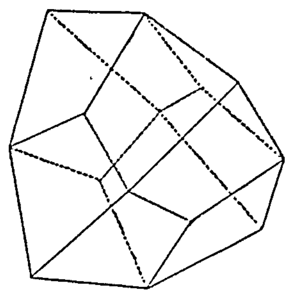


Fig. 357.

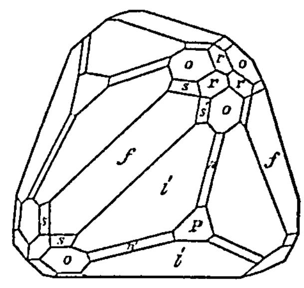


Fig. 358.

Stirling, Sandlodge in Shetland, Tomnadashin on Loch Tay, Kirkcudbright; Crinnis and other Cornish mines near St Austell; Harz, Müsen, Freiberg, Camsdorf, Alsace, Kremnitz, and Kapnik. Those with 17 to 31 silver are the *Silver Fahlore* (Freiberg). Ore of copper and silver.

238. Tennantite, $(CuS, FeS)\ As_2S_3$.

Cubic (like fig. 237). Cl. ∞O. Brittle. H. = 4; G. = 4·3 to 4·5. Iron-black; streak dark red, grey. C.c.: 49 copper, 4 iron, 19 arsenic, and 28 sulphur. Redruth and St Day (Cornwall), and Skutterud. *Copper-blende*, with brownish red streak; G. = 4·3; contains 8·9 zinc; Freiberg.

239. Polytelite (*Weissgiltigerz*), $4RS + Sb_2S_3$.

Like tetrahedrite. H. = 2·5; G. = 5·4 to 5·7. C.c.: silver 6 to 22, lead 38 to 52, antimony 8·5 to 22, sulphur 13 to 22·5. Freiberg.

240. Stephanite, $5Ag_2S + Sb_2S_3$.

Right prismatic. ∞P (*o*) 115° 39′; P (*P*) middle edge 104° 20′; $2\breve{P}\infty$ (*d*) middle edge 107° 48′; 0P (*s*); $\infty\breve{P}\infty$ (*p*) (figs. 333, 334). Cl. *d* and *p*, both imperfect; fracture conchoidal or uneven; sectile. H. = 2 to 2·5; G. = 6·2 to 6·3. Iron-black to blackish lead-grey. C.c.: 68·5 silver, 15·3 antimony, and 16·2 sulphur. Cornwall, Freiberg, Schneeberg, Annaberg, Joachimsthal, Przibram, Schemnitz, Mexico, Peru, and Siberia. Valuable ore of silver.

241. Geocronite, $5PbS + (Sb, As)_2S_3$.

Right prismatic. Fracture conchoidal; sectile. H. = 2 to 3; G. = 6·45 to 6·54. Pale lead-grey. C.c.: 67 lead, with 1 to 2 copper and iron, 16 antimony, with 4·7 arsenic, and 17 sulphur. Sala in Sweden, Meredo (Oviedo) in Spain, and near Pietrosanto in Tuscany.

242. Kilbrickenite, $6PbS + Sb_2S_3$.

Massive; granular or foliated. C.c.: 70·01 lead, 13·76 antimony, and 16·23 sulphur. County Clare in Ireland.

243. Polybasite, $9(Ag_2, Cu_2)S + (Sb, As)_2S_3$.

Hexagonal; P 117°. Crystals 0P, ∞P; and 0P, P, tabular. Cl. basal, imperfect; sectile, and easily frangible. H. = 2 to 2·5; G. = 6 to 6·25. Iron-black, in very thin lamellæ, translucent, red. C.c.: 64 to 72 silver, 3 to 10 copper, 16 to 17 sulphur, 0·2 to 8 antimony, and 1 to 6 arsenic. Freiberg, Joachimsthal, Schemnitz, Guanajuato, Nevada, and Idaho. Rich ore of silver.

244. Polyargyrite, $12AgS + Sb_2S_3$.

Cubic. Typical form O, $\infty O\infty$, ∞O, mOm. Cl. cubic. H. = 2·5; G. = 6·97. Metallic, iron-black; streak black. Malleable. C.c.: 78·2 silver, 7·4 antimony, 14·5 sulphur. Wolfach in Baden.

245. Enargite, $3Cu_2S + As_2S_5$.

Right prismatic. Cl. ∞P 97° 53′ perfect, brachydiagonal 100° 58′ and macrodiagonal less so. Typical form ∞P, 0P, $\infty\bar{P}\infty$, $\infty\breve{P}\infty$. Brittle. H. = 3; G. = 4·3 to 4·5. Iron-black. C.c.: 48·3 copper, 19·1 arsenic, and 32·6 sulphur. Morococha in Peru.

246. Clarite, $3CuS+AsS$.

Oblique prismatic. Cl. clinodiagonal. Ordinary form ∞P, $\infty P^c\infty$, $0P$, mP. H. = 3·5; G. = 4·46. Dark bluish grey. Kinzigthal in Baden. *Luzonite* is similar.

247. Famatinite, $3CuS+SbS$.

Right prismatic. Typical form $0P$, ∞P, $\infty \bar{P}\infty$, $\infty \breve{P}3$. Massive or reniform. H. = 3·5; G. = 4·57. Copper-red to grey; streak black. Famatina Mts. in the Argentine Republic, and Cerro de Pasco in Peru.

248. Chiviatite, $2PbS+3Bi_2S_3$.

Foliated, massive. G. = 6·9. Metallic. Lead-grey. Chiviato in Peru.

249. Epigenite, $6RS+As_2S_5$.

Right prismatic. ∞P 110° 50′. Steel-grey. H. = 3·5. Wittichen.

250. Epiboulangerite, $3PbS+Sb_2S_5$.

Right prismatic. G. = 6·3. Metallic. Blue-black. Altenburg in Silesia.

251. Xanthocon, $2(3AgS+As_2S_3)+(3AgS+As_2S_5)$.

Hexagonal rhombohedral. R : 0R 110° 30′. Crystals thin hexagonal tables; brittle, easily frangible. H. = 2 to 2·5; G. = 5 to 5·2. Translucent; adamantine. Orange-yellow or brown; streak darker. In the closed tube fuses easily, becomes lead-grey. C.c.: 63·4 silver, 14·7 arsenic, and 21·9 sulphur. Himmelsfürst mine at Freiberg.

252. Pyrostilpnite (*Fire-blende*).

Oblique prismatic; crystals like stilbite. $0P$ 139° 12′. Twins on orthodiagonal. H. = 2; G. = 4·2. Lustre pearly, and adamantine. Colour hyacinth-red and bright-yellow. Sectile. C.c.: 62·3 silver, with sulphur and antimony. Freiberg, Andreasberg, Przibram.

OXYSULPHURETS.

253. Kermesite, SbO_3+2SbS_3.

Oblique prismatic; crystals $\infty \bar{P}\infty$, $0P$, acicular and diverging; sectile. H. = 1 to 1·5; G. = 4·5 to 4·6. Translucent; adamantine. Cherry-red; streak similar. Sol. in h. acid. In potash solution becomes yellow, and dissolves. C.c.: 75·3 antimony, 19·8 sulphur, 4·9 oxygen. Bräunsdorf, Przibram, Pernek near Bösing (Hungary), Allemont, Southham (Canada).

254. Voltzine, $ZnO+4ZnS$.

Incrusting. H. = 4·5; G. = 3·7. Yellow. Pontgibaud and Joachimsthal.

255. Karelinite, $3BiO+BiS$.

H. = 2; G. = 6·6. Metallic. Lead-grey. Zavodinski in the Altai.

256. Bolivite, $Bi_2O_3+Bi_2S_3$.

Rhombohedral. From Bolivia.

SELENITES.

257. Chalcomenite, $\dot{C}u\ddot{S}e+2\dot{H}_2[=CuO,\ SeO_2+2H_2O]$.

Oblique prismatic, C 108° 20′. G. = 3·76. Bright blue. Transparent. C.c.: selenious acid 48·2, copper oxide 35·4, water 15·3. Cerro de Cacheuta (Mendoza, Argentine Republic).

NITRATES AND BORATES.

258. Nitratine, $\dot{N}a_2\ddot{\ddot{N}}_2[=Na_2O,\ N_2O_5]$.

Rhombohedral; R. 106° 30′. Tarapaca in Peru. Used in the arts as a substitute for nitre; but deliquesces in moist air.

259. Nitre (*Saltpetre*), $\dot{K}_2\ddot{\ddot{N}}_2[=K_2O,\ N_2O_5]$.

Right prismatic. ∞P (*M*) 118° 49′; $2\breve{P}\infty$ (*P*) 70° 55′; $\breve{P}\infty$ 109° 52′; $\infty \breve{P}\infty$ (*h*) (fig. 275); isomorphous with aragonite. Acicular, capillary, or pulverulent. Cl. indistinct; fracture conchoidal. H. = 2; G. = 1·9 to 2. Semitransparent; vitreous or silky. Colourless, white, or grey. Taste saline and cooling. Deflagrates when placed on hot charcoal; and B.B. on platina wire melts very easily, colouring the flame violet. C.c.: 46·6 potash and 53·4 nitric acid, but always more or less impure. In the limestone caves of many countries; Hungary, Spain, India. Used for producing nitric acid, in glass making, medicine, and the manufacture of gunpowder.

260. Nitrocalcite, $\dot{C}a\ddot{\ddot{N}}_2+\dot{H}_2$.

Fibrous or pulverulent. White or grey. C.c.: 30·8 lime, 59·3 nitric acid, and 9·9 water. Limestone caves of Kentucky; on old walls and limestone rocks.

261. Nitromagnesite, $\dot{M}g\ddot{\ddot{N}}_2+\dot{H}_2$.

Taste bitter. In the same places, and similar to nitrocalcite.

262. Boracite, $2\dot{M}g_3\ddot{B}_4+MgCl$.

Tesseral and hemihedral (figs. 63, 253, 359). Cl. octahedral, imperfect; fracture conchoidal; brittle. H. = 7; G. = 2·9 to 3. Transparent or translucent; vitreous or adamantine. Colourless or white, often greyish, yellowish, or greenish. Becomes polar electric by heat. B.B. fuses with difficulty to a clear yellowish bead, which on cooling forms a white opaque mass of needle-like crystals; at the same time colours the flame green. Sol. in h. acid. C.c.: 62·5 boracic acid, 26·9 magnesia, 7·9 chlorine, and 2·7 magnesium. Lüneberg, Segeberg in Holstein, Stassfurt.

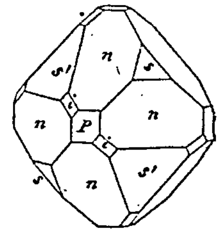


Fig. 359.

263. Stassfurtite.

In very minute prismatic crystals. White. C.c. same as boracite, and thus perhaps dimorphous. Stassfurt.

264. Rhodizite, $2\dot{C}a_3\ddot{B}_4$ (?).

H. = 8 and G. = 3·3 to 3·42; agrees in most characters with boracite. Pyro-electric. Mursinsk in Siberia.

265. Ludwigite, $2\dot{M}g\ddot{B}+\dot{F}e\ddot{F}e_2$.

Fibrous masses. From limestone at Morawitza in the Banat.

266. Borax (*Tinkal*), $\dot{N}a_22\ddot{B}+10\dot{H}_2$.

Oblique prismatic, C 73° 25′. ∞P 87°; P 122° 34′ (fig. 360). Almost isomorphous with augite; brittle. H. = 2 to 2·5; G. = 1·7 to 1·8. Pellucid; resinous. Colourless, or yellowish, greenish, and greyish white. Taste feebly alkaline and sweetish. C.c.: 16·4 soda, 36·5 boracic acid, and 47·1 water; but often with 2 phosphoric acid or other impurities. Shores of salt lakes in Tibet and Nepal, in California, and near Potosi.

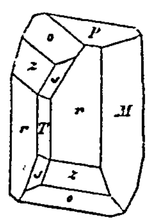


Fig. 360 (sp. 266).

267. Borocalcite, $\dot{C}a2\ddot{B}+6\dot{H}_2$.

Similar to ulexite (sp. 268); and from same locality.

268. Ulexite, $\dot{N}a_22\ddot{B}+2\dot{C}a2\ddot{B}+18\dot{H}_2$.

Fibrous. H. = 1; G. = 1·6. White. Tasteless. Iquique and Nova Scotia.

269. Szaibelyite, $2\dot{M}g_52\ddot{B}+3\dot{H}_2$.

H. = 3·5; G. = 2·7. Werksthal in Hungary.

270. Hydroboracite, $2\dot{C}a3\ddot{B}_3+2\dot{M}g3\ddot{B}_3+12\dot{H}_2$.

Radiating and foliated. Caucasus. A similar mineral, with soda in place of magnesia, is found in Peru.

271. Sussexite, $(\dot{M}n,\ \dot{M}g)_2\ddot{B}+\dot{H}_2$.

Fibrous, silky. White. H. = 3; G. = 3·4. Franklin (Sussex county, New Jersey).

ANHYDROUS CARBONATES.

272. Calcite (*Calc-spar, Calcareous Spar*), $\dot{C}a\ddot{C}$.

Hexagonal and rhombohedral; R 105° 5′ (fig. 101). The forms and combinations exceed those of any other mineral. Among them are more than fifty rhombohedrons, especially $-\frac{1}{2}R$ 135°; R; $-2R$ 79°; and 4R 66°; with 0R and ∞R as limiting forms. There are one hundred and fifty-five distinct scalenohedrons, as R3; R2; $\frac{1}{4}$R3; and the second hexagonal prism $\infty P2$. Hexagonal pyramids are among the rarer forms. Some of the most usual combinations are ∞R, $-\frac{1}{2}R$ (*c*, *g*, fig. 179); or $-\frac{1}{2}R$, ∞R, very frequent; also ∞R, 0R; likewise $-2R$, R (*f*, *P*, fig. 107); R3, ∞R, $-2R$; R5 (*y*), R3 (*r*), R (*P*), 4R (*m*), ∞R (*c*) (fig. 109); R, R3 (fig. 108). Several hundred distinct combinations are known.

Hemitropes and twins are not uncommon. These occur with the axes parallel (figs. 106, 146, 148, 180, 366, 367). Others

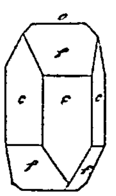


Fig. 361.

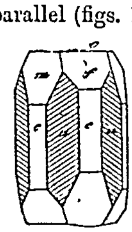


Fig. 362.

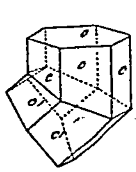


Fig. 363.

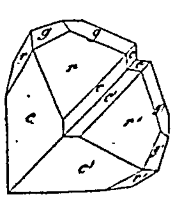


Fig. 364.

are conjoined by a face of R, the axes being almost at right angles, 89° 8′ (figs. 183, 369) or by a face of $-\frac{1}{2}R$, in which the chief axes form an angle of 127½°; and usually many times repeated, so that the centre crystals appear in lamellæ not thicker than paper (fig. 181); at an obtuse angle, as figs. 149, 363, or an acute

angle, as figs. 364, 368. Also occurs granular, lamellar, parallel or radiated fibrous, compact and earthy. Cl. rhombohedral along R, very perfect and easily obtained, so that the conchoidal fracture is rarely observable; brittle. H.=3; G.=2·6 to 2·8; pure transparent crystals=2·72. Pellucid in all degrees. Very distinct double refraction. Lustre vitreous, but several faces resinous, and 0R pearly. Most frequently colourless or white, but often grey, blue, green, yellow, red, brown, or black; streak greyish white. B.B. infusible, but becomes caustic and emits a bright light. Effervesces, and is entirely sol. in h. or n. acid. The fine powder, ignited on platina-foil over the spirit-lamp, forms a somewhat connected mass, and even adheres to the platina. C.c. of the purest varieties, carbonate of lime, with 44 carbonic acid and 56 lime, but usually contains magnesia and protoxide of iron or of manganese. Remarkable specimens of the crystallized variety or proper calc-spar are found at Alston Moor in Cumberland (flat rhombic crystals) and in Derbyshire (pale yellow

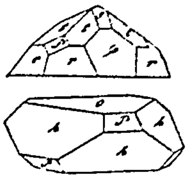


Fig. 365.

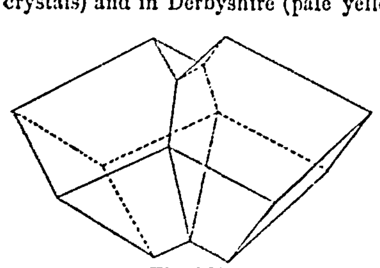


Fig. 366.

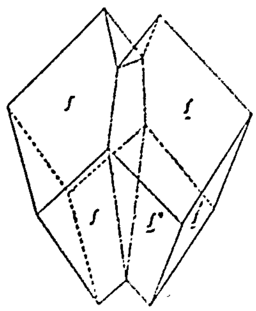


Fig. 367.

transparent pyramids), at Strontian, Elie in Fife (figs. 370, 371, 372), Andreasberg and other parts of the Harz (six-sided prisms), and at Freiberg, Tharand, and Maxen in Saxony.

Certain varieties are distinguished. *Iceland Spar*, remarkable for its transparency and double refraction, occurs massive and in huge crystals in a trap rock in Iceland. *Slate Spar*, thin lamellar, often with a shining white pearly lustre and greasy feel; Abergairn and Glen

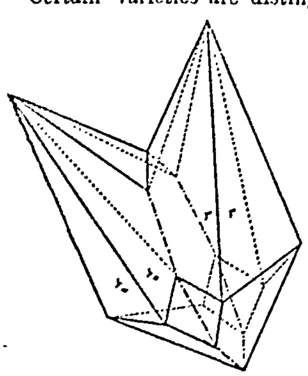


Fig. 368.

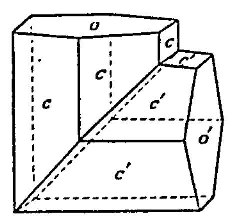


Fig. 369.

Tilt in Scotland, Wicklow in Ireland, and Norway. *Aphrite*, fine scaly; from Hesse and Thuringia. *Marble* is the massive crystalline variety of this mineral, produced by igneous action on compact limestone. Paros, Naxos, and Tenedos furnished the chief supply to the Grecian artists; Carrara, near the Gulf of Genoa, to those of modern times. Some of the coloured marbles

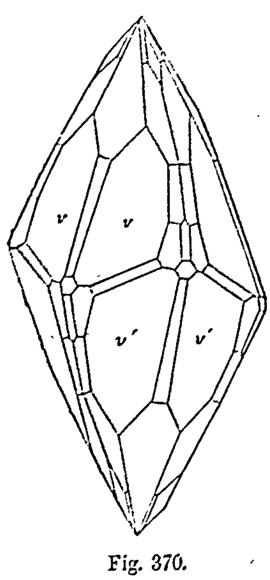


Fig. 370.

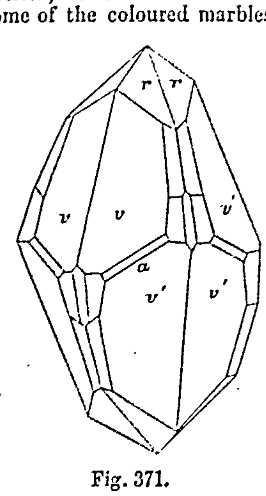


Fig. 371.

of the ancients were impure limestones, as the *Cipollino*, zoned with green talc or chlorite, and *Verde Antique*, mixed with green serpentine. *Ruin Marble* shows irregular markings like ruins; Val d'Arno (Florentine marble), and Bristol (Cotham marble). *Lucullite* from Egypt, and *Anthraconite*, from Campbelltown and Kilkenny, are black from carbon. *Lumachello*, from Bleiberg in Carinthia, exhibits beautiful iridescent colours from fossil shells, sometimes deep red or orange (*Fire Marble*). *Hislopite*, from Poonah, is green, from celadonite.

Limestone occurs in all formations under various names, as *Oolite*, egg-stone, or roe-stone,—round concretions with a concentric structure like the roe of a fish; *Pisolite*, or peastone, similar structure; *Chalk*, soft earthy; *Lithographic Stone*, yellowish and compact, from Solenhofen; and *Marl*, calcareous matter more or less mixed with clay. *Calcareous Tufa*, generally a recent deposit from calcareous springs, has often a loose friable texture, but at other times is hard and compact; and in the neighbourhood of Rome forms the common building stone *Travertino*. The sandstone of Fontainebleau is carbonate of lime ($\frac{1}{3}$) mixed with quartz sand ($\frac{2}{3}$), and occasionally crystallizing in rhombohedrons.

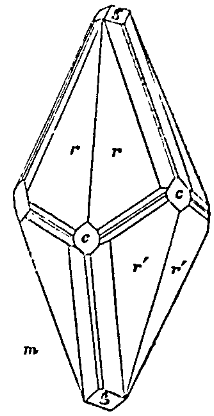


Fig. 372.

This mineral is employed in many ways:—the coarser varieties, when burnt to drive off the carbonic acid, as lime, for mortar, manure, tanning; as a flux in melting iron and other ores, or in preparing glass, and for similar purposes; the finer, as marbles, for sculpture, architecture, and ornamental stone-work; the chalk for writing, white-washing, or producing carbonic acid.

Plumbocalcite.—Cl. 104° 53′. White and pearly; softer than calc-spar; but G.=2·824. Contains 2·3 to 7·3 carbonate of lead. Wanlockhead and Leadhills (Scotland).

273. Dolomite (*Bitter-spar*), $\dot{\mathrm{Ca}}\ddot{\mathrm{C}}+\dot{\mathrm{Mg}}\ddot{\mathrm{C}}$.

Hexagonal rhombohedral; R 106° 15′–20′; most frequent form R. The rhombohedrons often curved and saddle-shaped; also granular or compact, often cellular and porous. Cl. rhombohedral. H.=3·5 to 4·5; G.=2·85 to 2·95. Translucent; vitreous, but often pearly. Colourless or white, but frequently pale red, yellow, or green. B.B. infusible, but becomes caustic, and often shows traces of iron and manganese. Fragments effervesce very slightly or not at all in hydrochloric acid; the powder is partially soluble, or wholly when heated. C.c.: 54·3 carbonate of lime and 45·7 carbonate of magnesia, but generally carbonate of lime with more than 20 per cent. carbonate of magnesia and less than 20 per cent. carbonate of iron.

Varieties are—*Dolomite*, massive-granular, easily divisible, white; *Rhomb* or *Bitter-spar*, larger grained, or distinctly crystallized and cleavable, often inclining to green; and *Brown-spar* and *Pearl-spar*, in simple crystals generally curved (fig. 231), or in imitative forms, of colours inclining to red or brown, more distinct pearly lustre, and under 10 per cent. carbonate of iron. Leadhills and Charlestown in Scotland, Alston in Cumberland, in Derbyshire, Traversella in Piedmont, St Gotthard, Gap in France. Greenish, twinned; Miemo in Tuscany (*Miemite*), and Tharand in Saxony (*Tharandite*).

The massive and compact varieties are very common, and are valued as building stones (cathedral of Milan, York Minster, and the Houses of Parliament at Westminster). The Parian marble, and also the Sutherland and Iona marbles, belong to this species.

274. Ankerite, $\dot{\mathrm{Ca}}\ddot{\mathrm{C}}+(\dot{\mathrm{Mg}}\dot{\mathrm{Fe}})\ddot{\mathrm{C}}$.

R 106° 12′. Usually massive and granular. G.=2·9 to 3·1. Otherwise like siderite. Unst (Shetland), Styria.

275. Magnesite, $\dot{\mathrm{Mg}}\ddot{\mathrm{C}}$.

Rhombohedral; 107° 10′–30′. Reniform or massive. H.=3·5; G.=2·85 to 2·95. Subtranslucent or opaque; streak shining. Snow-white, greyish or yellowish white, and pale yellow. Tyrol, Norway, North America.

276. Breunnerite (*Giobertite*), $\dot{\mathrm{Mg}}\ddot{\mathrm{C}}+(\dot{\mathrm{Mn}}\dot{\mathrm{Fe}})\ddot{\mathrm{C}}$.

Hexagonal rhombohedral; R 107° 10′–30′. Granular or columnar. Cl. R, very perfect. H.=4 to 4·5; G.=2·9 to 3·1. Transparent or translucent on the edges; highly vitreous. Colourless, but often yellowish brown or blackish grey. C.c. essentially carbonate of magnesia, with 51·7 carbonic acid and 48·3 magnesia, but often mixed with 8 to 17 carbonate of iron or manganese. Unst, Tyrol (in Fassa Valley, &c.), St Gotthard, Harz.

277. Siderite (*Sparry Iron, Chalybite*), $\dot{\mathrm{Fe}}\ddot{\mathrm{C}}$.

Hexagonal and rhombohedral; R 107°. Chiefly R, often curved, saddle-shaped (fig. 232), or lenticular. Cl. rhombohedral along R, perfect; brittle. H.=3·5 to 4·5; G.=3·7 to 3·9. Translucent in various degrees, becoming opaque when weathered; vitreous or pearly. Rarely white, generally yellowish grey or yellowish brown. changing

to red or blackish brown on exposure. B.B. infusible, but becomes black and magnetic; with borax and salt of phosphorus shows reaction for iron; with soda often for manganese. In acids soluble with effervescence. C.c. carbonate of iron, with 62·1 protoxide of iron and 37·9 carbonic acid, but usually 0·5 to 10 or even 25 protoxide of manganese, 0·2 to 15 magnesia, and 0·1 to 2 lime. Unst, Kintyre. In beds or masses in Beeralston in Devonshire, Alston Moor in Cumberland, and in many of the tin-mines in Cornwall, in Styria, Carinthia, and Westphalia; in veins in Anhalt and the Harz; also in the Pyrenees and the Basque provinces of Spain, as near Bilboa; in crystals at Joachimsthal, Freiberg, Klausthal.

Clay Ironstone, grey, blue, brown, or black,—G. = 2·8 to 3·5, H. = 3·5 to 4·5,—is an impure variety.

278. Dialogite (*Red Manganese*), ṀnC̈.

Hexagonal rhombohedral; R 106° 56′. Crystals often curved, lenticular, or saddle-shaped; also spherical, reniform, and columnar or granular. Cl. R, perfect. H. = 3·5 to 4·5; G. = 3·3 to 3·6. Translucent; vitreous or pearly. Rose-red to flesh-red; streak white. C.c.: 62 manganese protoxide and 38 carbonic acid. Freiberg, Schemnitz, Kapnik, Nagyag, Elbingerode, and near Sargans.

279. Cobaltspath, ĊoC̈o.

Rhombohedral and spheroidal. H. = 4; G. = 4 to 4·13. Peach-blossom-red; but dark externally. Schneeberg.

280. Smithsonite (*Calamine*), ŻnC̈.

Hexagonal rhombohedral; R 107° 40′. Usually reniform, stalactitic, and laminar or granular. Cl. R, perfect, but curved; fracture uneven, conchoidal; brittle. H. = 5; G. = 4·1 to 4·5. Translucent or opaque; pearly or vitreous. Colourless, but often pale greyish yellow, brown, or green. C.c.: 64·8 zinc oxide and 35·2 carbonic acid. Mendip in Somersetshire, Matlock in Derbyshire, compact at Alston Moor, Chessy near Lyons, Altenberg near Aix-la-Chapelle, Brilon in Westphalia, Tarnowitz in Silesia, Hungary, Siberia.

281. Aragonite, ĊaC̈.

Right prismatic. ∞P 116° 10′; P̆∞ 108° 26′. The most common combinations are ∞P̆∞ (*h*), ∞P̆ (*M*), P∞ (*k*, *P*) (fig. 275), generally long prismatic (like the separate crystals in fig. 184); ∞P̆∞, ∞P, 0P, generally short prismatic; crystals of 6P̆$\frac{3}{2}$, ∞P, P̆∞, 6P̆∞ (*q*) (fig. 373) acute pyramidal. But simple crystals are rare, from the great tendency to form twins, conjoined by a face of ∞P, and repeated either in linear arrangement (fig. 185) or in rosette grouping (fig. 186). Also columnar, fibrous, and in crusts, stalactites, and other forms. Cl. brachydiagonal, distinct; fracture conchoidal or uneven. H. = 3·5 to 4; G. = 2·9 to 3 (massive 2·7). Transparent or translucent; vitreous. Colourless, but yellowish white to brick-red; also light green, violet-blue, or grey. In the closed tube, before reaching a red heat, it swells, and falls down into a white coarse powder, evolving a little water. Unst and Leadhills; Valencia, Molina and elsewhere in Aragon; Leogang in Salzburg, and Antiparos. *Flos-ferri*, coralloid, in the iron-mines of Styria. *Satin-spar*, fine fibrous silky, at Dufton (Westmoreland). Stalactitic, coast of Galloway, Leadhills, Buckinghamshire, and Devonshire. Also deposited as tufa by the Carlsbad and other hot springs.

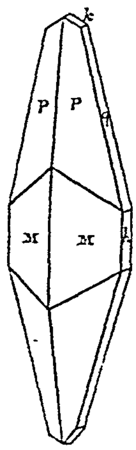


Fig. 373.

282. Witherite, ḂaC̈.

Right prismatic. ∞P (*g*) 118° 30′; 2P̆∞ (*P*) 112°. Crystals not common like fig. 275, but generally with quite an hexagonal aspect from being twinned like aragonite (fig. 374). Oftener spherical botryoidal, or reniform, with radiated-columnar structure. Cl. ∞P, distinct; fracture uneven. H. = 3 to 3·5; G. = 4·2 to 4·3. Semitransparent or translucent; vitreous, or resinous on the fracture. Colourless, but generally yellowish or greyish. B.B. fuses easily to a transparent globule, opaque when cold; on charcoal boils, becomes caustic and sinks into the support; soluble with effervescence in n. or h. acid. C.c.: 22·3 carbonic acid and 77·7 baryta. Alston Moor and Hexham in Northumberland, also in Styria, Salzburg, Hungary, Sicily, Siberia, and Chili.

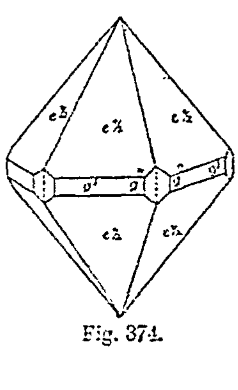


Fig. 374.

283. Alstonite, ḂaC̈ + ĊaC̈.

Right prismatic. ∞P 118° 50′; 2P̆∞ 111° 50′; usual combination P, 2P̆∞, ∞P, resembling an hexagonal pyramid (fig. 375). Cl. ∞P and ∞P̆∞, rather distinct. H. = 4 to 4·5; G. = 3·65 to 3·76. Translucent; weak resinous. Colourless or greyish-white. C.c.: 66 carbonate of baryta and 34 carbonate of lime. Fallowfield near Hexham, and Alston Moor.

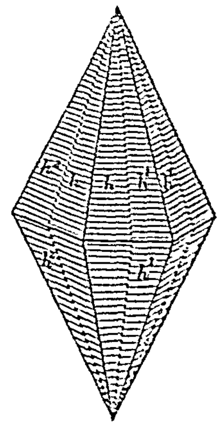


Fig. 375 (sp. 283).

284. Strontianite, ṠrC̈.

Right prismatic. ∞P 117° 19′; P̆∞ 108° 12′. Crystals (fig. 376) and twins like aragonite; also broad columnar and fibrous. Cl. prismatic along ∞P (*M*). H. = 3·5; G. = 3·6 to 3·8. Translucent or transparent; vitreous or resinous on fracture. Colourless, but often light asparagus- or apple-green, more rarely greyish, yellowish, or brownish. B.B. fuses in a strong heat only on very thin edges, intumesces in cauliflower-like forms, shines brightly, and colours the flame red; easily soluble in acids, with effervescence. C.c.: 30 carbonic acid and 70 strontia, but often contains carbonate of lime (6 to 8). Strontian in Argyllshire, Sutherland, Leogang in Salzburg, Bräunsdorf in Saxony, Hamm in Westphalia, the Harz; at Schoharie (N.Y.) and elsewhere in United States (*Emmonite*). It is used to produce red fire in pyrotechnic exhibitions.

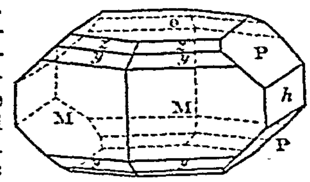


Fig. 376.

285. Manganocalcite, (Ṁn, Ċa, Ḟe) C̈.

Right prismatic; in prisms like aragonite, and bears the same relation to dialogite that aragonite does to calc-spar. H. = 4 to 5; G. = 3·03. Red or reddish white. Vitreous. Schemnitz.

286. Cerussite (*Lead Spar*), ṖbC̈.

Right prismatic; isomorphous with aragonite and nitre. ∞P (*M*) 117° 14′; P̆∞ 108° 16′; 2P̆∞ (*u*) 69° 20′; also 0P; P (*t*); ½P̆∞ (*s*); ∞P̆∞ (*l*); ∞P̆3 (*c*) (fig 377). Twins common (figs. 158, 159, 378, 379). Also granular or earthy. Cl. ∞P and 2P̆∞, rather distinct; fracture conchoidal; easily frangible. H. = 3 to 3·5; G. = 6·4 to 6·6. Transparent or translucent; adamantine or resinous. Colourless and often white, but also grey, yellow, brown, black, rarely green, blue, or red; streak white. B.B. decrepitates violently, but easily fused and reduced; soluble with effervescence in n. acid. C.c.: 83·5 protoxide of lead and 16·5 carbonic acid. Very common. Leadhills, Wanlockhead, Keswick, Alston Moor, Beeralston in Devonshire, St Minver in Cornwall; Przibram, Mies, and Bleistadt; Tarnowitz, Johann-Georgenstadt, Zellerfeld, Klausthal, and many other places.

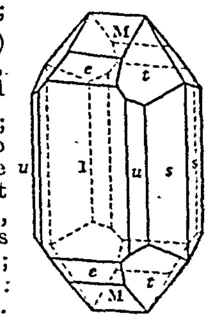


Fig. 377.

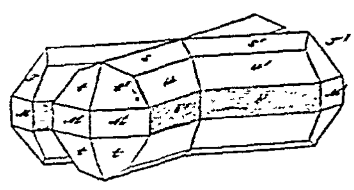


Fig. 378.

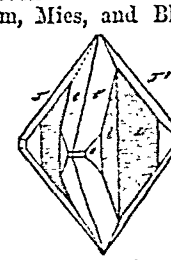


Fig. 379.

287. Baryto-Calcite, ḂaC̈ + CaC̈.

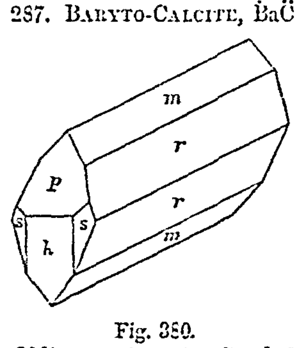


Fig. 380.

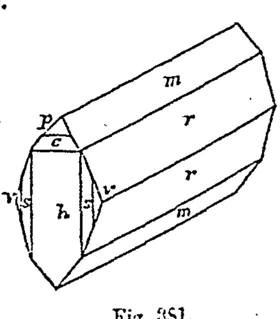


Fig. 381.

Oblique prismatic, C 69° 30′. ∞P (*m*) 84° 52′, P (*s*) 106° 54′,

$P^{\circ}\infty$ (*h*) 61° (figs. 380, 381); also columnar and granular. Cl. P perfect, $P^{\circ}\infty$ less perfect. H. = 4; G. = 3·6 to 3·7. Transparent or translucent; vitreous, inclining to resinous. Yellowish white. C.c.: like alstonite. Alston Moor.

288. Bismuto-sphærite, $\dddot{B}i_2\ddot{C}$.

Small fibrous brown concretions from Neustädtel, near Schneeberg.

HYDROUS CARBONATES.

289. Thermonatrite, $\dot{N}a_2\ddot{C}+\dot{H}_2$.

Right prismatic. $\infty\breve{P}2$ (*d*) 107° 50′; $\breve{P}\infty$ (*o*) 83° 50′; with $\infty\breve{P}\infty$ (*P*) in rectangular tables (fig. 382). Cl. brachydiagonal, perfect. H. = 1·5; G. = 1·5 to 1·6. Colourless. B.B. like natron, but does not melt. C.c.: 50·1 soda, 35·4 carbonic acid, and 14·5 water. Natron lakes of Lagunilla in Venezuela, of Lower Egypt, and of the steppes between Urals and Altai.

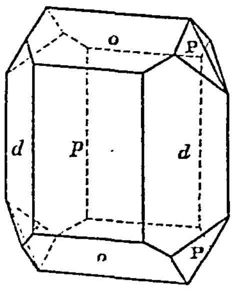


Fig. 382 (sp. 289).

290. Natron, $\dot{N}a_2\ddot{C}+10\dot{H}_2$.

Oblique prismatic, C 57° 40′. Crystals artificial; with ∞P 79° 41′; P 76° 28′. Cl. orthodiagonal, distinct. H. = 1 to 1·5; G. = 1·4 to 1·5. Pellucid; vitreous. Colourless or greyish white. B.B. melts easily, colouring the flame yellow. C.c.: 22 soda, 15 carbonic acid, and 63 water; but mixed with chloride of sodium and other salts. Only as an efflorescence on the ground or rocks (lava of Vesuvius and Etna) in various countries (Hungary, Egypt, Tartary), and in mineral springs and lakes. Used in the manufacture of soap, in dyeing, and in bleaching.

291. Trona, Urao, $\dot{N}a_2\ddot{C}_3+4\dot{H}_2$.

Oblique prismatic. Crystals 0P (*T*), $\infty P^{\circ}\infty$ (*M*), P (*n*). *T* : *M* 103° 15′ (fig. 383). Cl. orthodiagonal, perfect. H. = 2·5 to 3; G. = 2·1 to 2·2. Transparent to translucent. Colourless. Does not decompose in the air. Taste alkaline. C.c.: 38 soda, 40 carbonic acid, and 22 water. Fezzan and Barbary (*Trona*), Lagunilla (*Urao*).

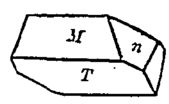


Fig. 383.

292. Gaylussite, $\dot{N}a_2\ddot{C}+\dot{C}a\ddot{C}+5\dot{H}_2$.

Oblique prismatic, C 78° 27′. Cl. ∞P, imperfect; fracture conchoidal. H. = 2·5; G. = 1·9 to 1·95. Transparent; vitreous. Colourless. C.c.: 34·5 carbonate of soda, 33·6 carbonate of lime, 30·4 water, with 1·5 clay. Lagunilla.

293. Hydromagnesite, $\dot{M}g_4\ddot{C}_3+4\dot{H}_2$.

Oblique prismatic. ∞P 88° nearly. Crystals small, rare; also massive. H. = 1·5 to 3; G. = 2·14 to 2·18. Vitreous or silky. White. C.c.: 36·2 carbonic acid, 44 magnesia, and 19·8 water. Unst (Shetland), Moravia, Kumi in Negropont, Hoboken in New Jersey, and Texas in Pennsylvania.

294. Azurite (*Blue Copper*), $\dot{C}u_3\ddot{C}_2+\dot{H}_2$.

Oblique prismatic, C 87° 39′. ∞P (*M*) 99° 32′; − P (*k′*) 106° 14′. Crystals 0P, ∞P, $\infty P^{\circ}\infty$, − P (or *h*, *M*, *s*, *k′*, in fig. 384, but in another position); also radiated and earthy. Cl. clinodomatic (*P*) 59° 14′, rather perfect; fracture conchoidal or splintery. H. = 3·5 to 4·2; G. = 3·7 to 3·8. Translucent or opaque; vitreous. Azure-blue, the earthy varieties (and streak) smalt-blue. B.B. on charcoal fuses and yields a grain of copper; soluble with effervescence in acids, and also in ammonia. C.c.: 69·1 protoxide of copper, 25·7 carbonic acid, and 5·2 water. Crystals at Redruth, Alston Moor, Chessy near Lyons, in Siberia, Moldawa in the Banat, Burra-Burra (Australia). Valued as an ore of copper.

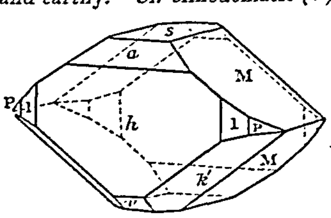


Fig. 384.

295. Malachite, $\dot{C}u_2\ddot{C}+\dot{H}_2$.

Oblique prismatic, C 61° 50′. ∞P 104° 20′. Crystals ∞P (*M*), $\infty P^{\circ}\infty$ (*s*), 0P (*P*), in hemitropes (fig. 385). In general acicular, scaly, or reniform, stalactitic, and radiated fibrous. Cl. basal and clinodiagonal, very perfect. H. = 3·5 to 4; G. = 3·6 to 4. Transparent or translucent on the edges; adamantine, vitreous, silky, or dull. Emerald and other shades of green; streak apple-green. B.B. and with acids like azurite. C.c.: 71·8 copper protoxide (= 57·5 copper), 20 carbonic acid, and 8·2 water. Crystalline at Rheinbreitenbach on the Rhine and Zellerfeld in the Harz; fibrous and compact at Sandlodge in Shetland, Leadhills, Cornwall, Wales, and Ireland, at Chessy in France, Siberia, the Urals, Saalfeld in Thuringia, Moldawa in the Banat, in North America, Africa, and Australia. Frequently pseudomorphous after copper and its ores, also after calcite and cerussite. Valuable ore of copper; the finer varieties are prized for ornamental purposes.

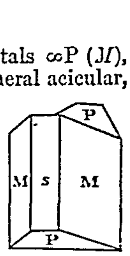


Fig. 385.

296. Hydrozincite, $\dot{Z}n\ddot{C}+2\dot{Z}n\dot{H}_2$.

Massive. C.c.: zinc oxide 75·3, carbonic acid 13·6, water 11·1. Spain, Westphalia, Bavaria, Persia, United States. Valuable ore.

297. Aurichalcite, $2\dot{C}u\ddot{C}+3\dot{Z}n\dot{H}_2$.

Acicular. H. = 2. Translucent, pearly, and verdigris-green. C.c.: 29·2 copper protoxide, 44·7 zinc oxide, 16·2 carbonic acid, and 9·9 water. Leadhills, Matlock, Loktevski in the Altai.

298. Emerald-Nickel (*Zaratite*), $\dot{N}i\ddot{C}+6\dot{H}_2$.

Amorphous, reniform, and incrusting. H. = 3; G. = 2·6 to 2·7. Translucent; vitreous. Emerald-green. C.c.: 59·3 nickel protoxide, 11·7 carbonic acid, and 29 water. On chromite at Hagdale in Unst, Texas in Pennsylvania; also Cape Ortegal in Spain, Tyrol, and Ekaterinburg in the Urals.

299. Lindakerite, $\ddot{U}_2\ddot{C}+2\dot{C}a\ddot{C}+10\dot{H}_2$.

In small siskin-green crystalline aggregates. H. = 2·5 to 3. From Elias mine near Joachimsthal, implanted on pitch-blende.

300. Voglite, $4\ddot{U}\ddot{C}+7\dot{C}a\ddot{C}+3\dot{C}u\ddot{C}+24\dot{H}_2$.

Rhomboidal. Emerald-green scales with pearly lustre. Elias mine, Joachimsthal.

301. Liebigite, $\ddot{U}_2\ddot{C}+\dot{C}a\ddot{C}+20\dot{H}_2$.

Mammillary concretions. H. = 2 to 2·5. Apple-green. Adrianople, Joachimsthal, and Johann-Georgenstadt.

302. Bismuthite, $\dddot{B}i_4\ddot{C}_3+4\dot{H}_2$.

Disseminated, investing or acicular; fracture conchoidal or uneven; very brittle. H. = 4 to 4·5; G. = 6·8 to 6·91. Opaque; dull vitreous. Grey, yellow, or green. C.c.: 90·1 bismuth oxide, 6·4 carbonic acid, and 3·5 water. Ullersreuth (Reuss), Schneeberg, Johann-Georgenstadt; also Chesterfield in South Carolina.

303. Lanthanite, $\dot{L}a\ddot{C}+3\dot{H}_2$.

Right prismatic. ∞P 92° 46′. Small tabular crystals; usually granular or earthy. Cl. basal. H. = 2; G. = 2·7. Dull or pearly. White or yellowish. C.c.: 21 carbonic acid, 55 lanthanum oxide, and 24 water. Bastnaes in Sweden, Lehigh in Pennsylvania.

CARBONATES WITH HALOID SALTS, &c.

304. Phosgenite, $PbCl+\dot{P}b\ddot{C}$.

Pyramidal. P 113° 56′. Crystals short-prismatic or sharp-pyramidal. Cl. ∞P, rather perfect; fracture conchoidal. H. = 2·5 to 3; G. = 6 to 6·2. Transparent or translucent; resinous adamantine. White, yellow, green, or grey. C.c.: 51 chloride and 49 carbonate of lead. Very rare. Stottfield near Elgin in Scotland, Matlock and Cromford in Derbyshire, Tarnowitz.

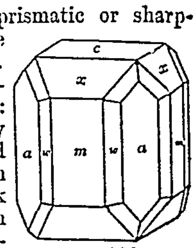


Fig. 386.

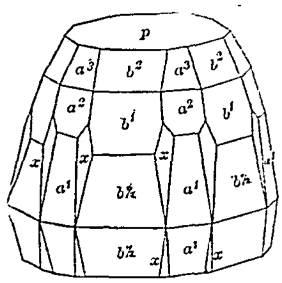


Fig. 387 (sp. 305).

305. Parisite, $3\dot{C}e\ddot{C}+CaF$.

Hexagonal. P 164° 58′. Cl. basal, perfect. H. = 4·5; G. = 4·35. Vitreous; on cleavage-plane pearly. Brownish yellow, inclining to red. C.c.: 23·5 carbonic acid, 42·5 protoxide of cerium, 8·2 lanthanum oxide, 9·6 didymium oxide, 2·8 lime, 10·1 fluoride of calcium, and 2·2 fluoride of cerium. Emerald mines of the Muzo Valley in Colombia, Urals.

306. Leadhillite (*Maxite*), $Pb_{18}C_5S_5O_{51}+5\dot{H}_2$.

Right prismatic. P middle edge 137°; ∞P 120° 20′; $2\breve{P}\infty$ 43° 12′.

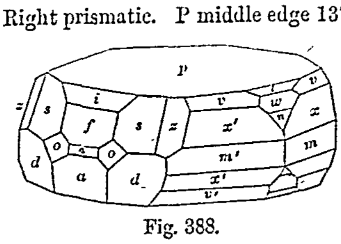


Fig. 388.

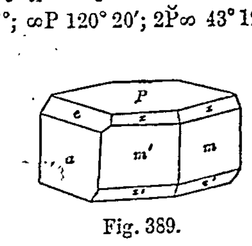


Fig. 389.

Mostly tabular; also twins. Cl. basal, perfect; slightly brittle. H. = 2·5; G. = 6·26 to 6·44. Transparent or translucent; resinous

acid with effervescence. C.c.: sulphate of lead 57·6, oxide of lead 42·4. Leadhills; rare.

HYDROUS SULPHATES.

318. MIRABILITE (*Glauber Salt*), $\dot{N}a_2\dddot{S}+10\dot{H}_2$.

Oblique prismatic, C 72° 15′. Cl. orthodiagonal; fracture conchoidal. H.=1·5 to 2; G.=1·4 to 1·5. Pellucid and colourless. C.c.: 19·2 soda, 24·8 sulphuric acid, and 56 water. As an efflorescence in quarries, on old walls, or on the ground; in the waters of lakes and springs in Russia and Egypt, and on Vesuvius on lava.

319. GYPSUM, $\dot{C}a\dddot{S}+2\dot{H}_2$.

Oblique prismatic, C 80° 57′. The most common forms are ∞P 111° 30′; P 138° 40′; −P 143° 30′; and ∞P∞. Two common combinations are ∞P(*f*), ∞P∞ (*p*), −P (*l*) (fig. 129), and this with P. Lenticular crystals often occur; hemitropes frequent (figs. 161, 150, 151); also granular, compact, fibrous, scaly, or pulverulent. Cl. clinodiagonal perfect, along P much less perfect; sectile; thin plates flexible. H.=1·5 to 2 (lowest on P); G.=2·2 to 2·4. Transparent or translucent; vitreous, on cleavage pearly or silky. Colourless, and snow-white, but often red, grey, yellow, brown, and more rarely greenish or bluish. In the closed tube yields water. B.B. becomes opaque and white; soluble in 400 to 500 parts of water, scarcely more so in acids. C.c.: 46·5 sulphuric acid, 32·6 lime, and 20·9 water.

Transparent crystals, or *Selenite*, occur in the salt-mines of Bex in Switzerland, of the Tyrol, Salzburg, and Bohemia, in the sulphur-mines of Sicily, at Lockport in New York, in porphyry at Gourock, in the clay of Shotover Hill near Oxford, at Chatley near Bath, and many other localities. Fibrous gypsum at Campsie, Matlock in Derbyshire, and at Ilfeld in the Harz. Compact gypsum in whole beds in many parts of England, Germany, France, and Italy, at Volterra in Tuscany (*Alabaster*) often with rock-salt. The finer qualities (or alabaster) are cut into various ornamental articles.

320. KIESERITE, $\dot{M}g\dddot{S}+\dot{H}_2$.

Rhombic, but chiefly massive. G.=2·52. Pellucid; greyish white. C.c.: magnesia 29, sulphuric acid 58, water 13. In beds at Stassfurt.

321. EPSOMITE (*Epsom Salt*), $\dot{M}g\dddot{S}+7\dot{H}_2$.

Right prismatic. P mostly hemihedric; ∞P 90° 38′. ∞P (*M*), ∞P̆∞ (*o*), P (*l*) (fig. 399). Granular, fibrous, or earthy. Cl. brachydiagonal, perfect. H.=2 to 2·5; G.=1·75. Pellucid; vitreous; and white. Taste bitter. C.c.: 16·32 magnesia, 32·53 sulphuric acid, and 51·15 water. Efflorescence on various rocks, as at Hurlet near Paisley, Idria, Montmartre, and Freiberg; on the ground in Spain and the Russian steppes; in mineral waters, as at Epsom in Surrey, Saidschitz and Seidlitz in Bohemia. Used in medicine.

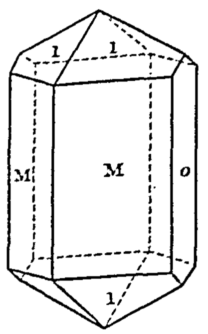


Fig. 399 (sp. 321).

322. GOSLARITE (*White Vitriol*), $\dot{Z}n\dddot{S}+7\dot{H}_2$.

Right prismatic. ∞P 90° 42′; isomorphous with epsomite. ∞P, ∞P̆∞, P (*M*, *o*, *l*) (fig. 399). Mostly granular or stalactitic; reniform and incrusting. Cl. brachydiagonal, perfect. H.=2 to 2·5; G.=2 to 2·1. Pellucid; vitreous. White, inclining to grey, yellow, green, or red. Taste nauseous-astringent. C.c.: 28·2 zinc oxide, 27·9 sulphuric acid, and 43·9 water. Holywell in Flintshire, Cornwall, Rammelsberg near Goslar in the Harz, Falun, Schemnitz. Used in dyeing and medicine.

323. MORENOSITE, $\dot{N}i\dddot{S}+7\dot{H}_2$.

Acicular, fibrous, and as an efflorescence. H.=2 to 2·25; G.=2. Lustre vitreous. Apple-green; streak white. Soluble. Morvern in Argyllshire, Cape Ortegal (Spain), Lake Huron, Pennsylvania.

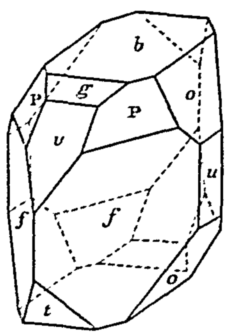


Fig. 400 (sp. 324).

324. MELANTERITE (*Green Vitriol, Copperas*), $\dot{F}e\dddot{S}+7\dot{H}_2$.

Oblique prismatic, C 75° 45′. ∞P (*f*) 82° 22′; −P (P) 101° 34′; P∞ (*o*) 67° 30′ (fig. 400); chiefly stalactitic, reniform, or in crusts. Cl. basal, perfect; prismatic less so. H.=2; G.=1·8 to 1·9. Translucent, rarely transparent; vitreous. Leek- or mountain-green, often with a yellowish coating; streak white. C.c.: 26 protoxide of iron, 29 sulphuric acid, and 45 water. Hurlet near Paisley, Bodenmais, Rammelsberg, Falun, Schemnitz, Bilin. Used in dyeing, and in manufacturing ink, Prussian blue, and sulphuric acid.

325. SMIKITE, $\dot{M}n_2\dddot{S}+\dot{H}_2$.

Stalactitic aggregates. Rose to white. Felsöbanya (Hungary).

326. MALLARDITE, $\dot{M}n\dddot{S}+7\dot{H}_2$.

Crystalline foliated masses; apparently oblique prismatic. Lucky Bay mine in Utah.

327. BIEBERITE (*Cobalt Vitriol*), $\dot{C}o\dddot{S}+7\dot{H}_2$.

Oblique prismatic; usually stalactitic, or an efflorescence. Pale rose-red. C.c.: 20 cobalt oxide, 4 magnesia, 29 sulphuric acid, and 47 water. Bieber near Hanau, and Leogang.

328. ALUNOGENE (*Hair-Salt*), $\dddot{A}l\,3\dddot{S}+18\dot{H}_2$.

Capillary or acicular, in crusts or reniform masses. H.=1·5 to 2; G.=1·6 to 1·7. Silky. White, inclining to green or yellow. C.c.: 36 sulphuric acid, 15·4 alumina, 48·6 water. Volcanoes of South America, in coal and lignite in Germany, and on old walls.

329. ALUMINITE (*Websterite*), $\dddot{A}l\dddot{S}+9\dot{H}$.

Reniform, and very fine scaly, or fibrous. Fracture earthy; sectile or friable. H.=1; G.=1·7. Opaque; dull or glimmering; snow-white or yellowish white. C.c.: 29·8 alumina, 23·2 sulphuric acid, and 47 water. Newhaven in Sussex; Epernay, Auteuil, and Lunel Vieil in France; Halle and Morl in Prussia. *Felsöbanyite*, from Hungary, in rhombic tubes, is similar, but has 10 per cent. of water.

330. COQUIMBITE, $\dddot{F}e\,3\dddot{S}+9\dot{H}_2$.

Hexagonal. P 58°. Crystals 0P; with ∞P and P; usually granular. Cl. ∞P, imperfect. H.=2 to 2·5; G.=2 to 2·1. White, also brown, yellow, red, and blue. C.c.: 28·5 iron peroxide, 42·6 sulphuric acid, and 28·9 water. Copiapo in Chili, and Calama in Bolivia.

331. COPIAPITE, $2\dddot{F}e_2 5\dddot{S}+13\dot{H}_2$.

Six-sided tables, but system uncertain; also granular. Cl. perfect. Translucent; pearly. Yellow. C.c.: 34 iron peroxide, 42 sulphuric acid, and 24 water. Copiapo in Chili. Also radiated-fibrous masses, dirty greenish yellow, incrusting the former, with 32 sulphuric acid and 37 water. Both probably mixtures.

Fibroferrite, also from Chili, and *Yellow Iron Ore*, from the brown coal at Kolosoruk in Bohemia and Modum in Norway, are both reniform, or compact and earthy. H.=2·5 to 3; G.=2·7 to 2·9. Colour ochre-yellow. *Apatelite*, reniform-earthy, yellow, from Auteuil near Paris, is similar; also *Vitriol Ochre* from Falun. *Misy*, from Rammelsberg in the Harz, containing sulphates of iron, copper, zinc, and other metals, is a product of decomposition.

332. PISSOPHANE, $(\dddot{A}l_2\dddot{F}e_2)_2\dddot{S}+15\dot{H}_2$.

Stalactitic; fracture conchoidal; very easily frangible. H.=2; G.=1·9 to 2. Transparent or translucent; vitreous. Olive-green to liver-brown; streak greenish white to pale yellow. C.c.: 7 to 35 alumina, 10 to 40 iron peroxide, 12 sulphuric acid, and 41 water. Saalfeld and Reichenbach in Saxony.

Carphosiderite, reniform, opaque, resinous, and straw-yellow, with a greasy feel, is related. H.=4·5; G.=2·5. Consists of hydrous sulphate of iron. Labrador.

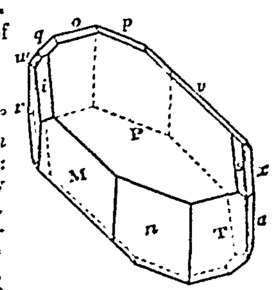


Fig. 401 (sp. 333).

333. CHALCANTHITE, $\dot{C}u\dddot{S}+5\dot{H}_2$.

Anorthic. ∞P̆∞ (*n*) : ∞P̆∞ (*r*) 79° 19′. P′ (*P*) : ∞P′ (*T*) 127° 40′. *P* : *n* 120° 50′. *P* : *r* 103° 27′. ∞P′ (*T*) : ∞′P (*M*) 123° 10′ (fig. 401). Generally incrusting. Cl. *T* and *M*, imperfect. H.=2·5; G.=2·2. Blue. C.c.: 32 protoxide of copper, 32 sulphuric acid, 36 water. Cornwall, Wicklow, Hungary, Tyrol, Falun, and on lava of Vesuvius.

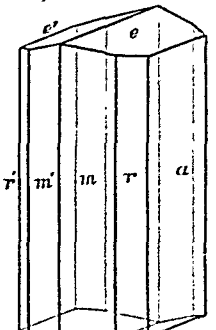


Fig. 402 (sp. 334).

334. BROCHANTITE, $\dot{C}u\dddot{S}+3\dot{C}u\dot{H}_2$.

Right prismatic. ∞P 104° 32′; P̆∞ 152° 37′; and ∞P̆∞; also reniform. Cl. brachydiagonal, perfect. H.=3·5 to 4; G.=3·75 to 3·9. Transparent or translucent; vitreous. Emerald or blackish green; streak bright green. C.c.: 70 copper protoxide, 18 sulphuric acid, and 12 water. Sandlodge (Unst), Roughton Gill in Cumber-

land, Rezbanya, Ekaterinburg; also Krisuvig in Iceland (*Krisuvigite*).

335. LANGITE, $\dot{C}u\dddot{S}+3\dot{C}u\dot{H}_2+2\dot{H}_2$.

Right prismatic. ∞P 123° 44′. Crystals long-tabular, mostly in twins. Also in fibro-lamellar and concretionary crusts, with earthy surface. Cl. basal and brachydiagonal. H. = 2·5; G. = 3·5. Vitreous. Greenish blue. C.c.: 65·1 copper protoxide, 16·4 sulphuric acid, and 18·5 water. Cornwall.

Warringtonite is similar; also *Konigine* from Siberia.

336. JOHANNITE (*Uran-vitriol*).

Oblique prismatic, C 85° 40′. ∞P 69°. Crystals similar to trona (No. 291, fig. 383), but minute; arranged in concretionary and reniform masses. H. = 2 to 2·5; G. = 3·19. Semitransparent; vitreous. Soluble. Taste bitter. Bright grass-green. C.c.: oxides of uranium 67·72, oxide of copper 5·99, sulphuric acid 20·02, water 5·59. Joachimsthal (Bohemia), Johann-Georgenstadt.

337. BLÖDITE (*Astrakanite*), $(\dot{M}g\dot{N}a_2)\dddot{S}+2\dot{H}_2$.

Oblique prismatic, C 100° 43′. $\infty P^{o}2$ 112° 55′; ∞P (*m*), $\infty P^{c}\infty$ (*b*), $\infty P^{o}2$ (*n*), $\infty P^{o}\infty$ (*a*), $-P$ (*p*), $P^{c}\infty$ (*d*), 0P (*c*) (fig. 403). In prismatic crystals, or efflorescent. H. = 3·5; G. = 2·2. Transparent. White or red. C.c.: 47·9 sulphuric acid, 8·5 soda, 12 magnesia, and 21·5 water. Salt lakes on the Volga near Astrakhan, Ischl, Stassfurt, and near Mendoza in South America.

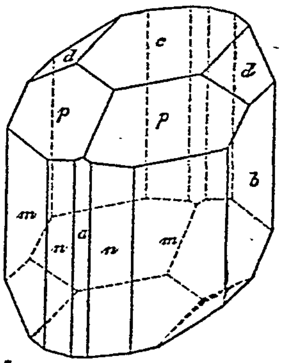


Fig. 403 (sp. 337).

Reussine from Seidlitz is similar, but a mixture.

338. LOWEITE, $2(\dot{N}a_2\dddot{S}+\dot{M}g\dddot{S})+5\dot{H}_2$.

Pyramidal, but only compact. Cl. basal, distinct; also octahedral, with angles 110° 44′ and 105° 2′. H. = 2·5 to 3; G. = 2·376. Vitreous. Yellowish white to flesh-red. C.c.: 20 soda, 13 magnesia, 52 sulphuric acid, and 15 water. Ischl.

339. SYNGENITE, $\dot{K}_2\dddot{S}+\dot{C}a\dddot{S}+\dot{H}_2$.

Oblique prismatic, C 76°. ∞P 73° 55′. Crystals $\infty P^{o}\infty$ (*a*), $\infty P^{c}\infty$ (*b*), 0P (*c*), ∞P (*p*), $\infty P^{o}2$ (*p″*), $\infty P^{o}3$ (*p‴*), $2P^{o}2$ (*c′*), P (*o′*), 2P (*o″*), $P^{c}\infty$ (*q*) $-P^{o}\infty$ (*r*), $P^{o}\infty$ (*r′*), $2P^{o}\infty$ (*r″*), $-\frac{2}{3}P^{o}\infty$ (*ρ*). Cl. ∞P, perfect; fracture conchoidal. H. = 2·5; G. = 2·25. Colourless to milk-white. C.c.: lime 16·88, potash 28·55, sulphuric acid 48·45, water 5·47. Soluble in 400 parts of water. In cavities in halite at Kalusz (Galicia).

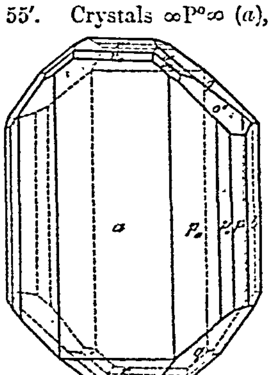


Fig. 404 (sp. 339).

340. POLYHALITE, $2\dot{C}a\dddot{S}+\dot{M}g\dddot{S}+\dot{K}_2\dddot{S}+2\dot{H}_2$.

Right prismatic. ∞P 115°. Mostly fibrous. H. = 3·5; G. = 2·7 to 2·8. Translucent; resinous. Colourless, generally brick-red. C.c.: sulphate of lime 45, of magnesia 20·5, of potash 29, water 5·5. Ischl, Aussee, and Berchtesgaden.

341. ALUM, $\dot{R}\dddot{S}+(\ddot{A}l_2\ddot{F}e_2)\dddot{S}_3+24\dot{H}_2$.

Cubic. O, sometimes with $\infty O\infty$ and $O\infty$. Generally efflorescent in fibrous crusts. Cl. octahedral; fracture conchoidal. H. = 2 to 2·5; G. = 1·75 to 1·9. Translucent. White. Taste sweetish-astringent. Soluble. B.B. evolves sulphurous fumes. (*a*) *Potash Alum*: $\dot{R}O = K_2O$; 33·7 sulphuric acid, 10·9 alumina, 9·9 potash, and 45·5 water. In the coal formation at Hurlet and Campsie in Scotland; the Tertiary brown coals of Hesse and the Rhine; the Lias near Whitby; Silurian alum slates of Scotland, Norway, and Sweden; the volcanic formations of the Lipari Islands, Sicily, and the Azores. (*b*) *Ammonia Alum*: $RO = (NH_4O)_2$; about 4 per cent. oxide of ammonium and 48 water. In closed tube forms a sublimate of sulphate of ammonia. Tschermig in Bohemia. (*c*) *Soda Alum*: $RO = Na_2O$; with 7 of soda and 48 water. Mendoza in South America, Solfatara near Naples, and Milo. (*d*) *Magnesia Alum*: $RO = MgO$. Translucent and silky. South Africa, Iquique in Peru (*Pickeringite*). (*e*) *Iron Alum* (*Feather Alum*): $RO = FeO$. Hurlet near Paisley, Mörsfeld in Bavaria, Krisuvig in Iceland. (*f*) *Manganese Alum*: $RO = MnO$. From Delagoa Bay in South Africa. An alum with 3·7 oxide of zinc occurs at Felsöbanya, and has been termed *Dietrichite*.

342. VOLTAITE, $3(\dot{F}e, \dot{K}_2)\dddot{S}+2(\ddot{F}e_2\ddot{A}l_2)\dddot{S}+12\dot{H}_2$.

Cubic. O; $\infty O\infty$; $O\infty$. Black, brown, or green. H. = 3; G. = 2·79. Solfatara near Naples, Goslar in the Harz, and Kremnitz.

343. ALUNITE, $\dot{K}_2\dddot{S}+3\ddot{A}l_2\dddot{S}+6\dot{H}_2$.

Rhombohedral; R 89° 10′. Crystals R and 0R (fig. 405); also earthy. Cl. basal. H. = 3·5 to 4; G. = 2·6 to 2·8. Translucent; vitreous, pearly on O. Colourless, but often stained. Hungary, Tolfa (near Civita Vecchia), Lipari Islands, Auvergne, and Milo.

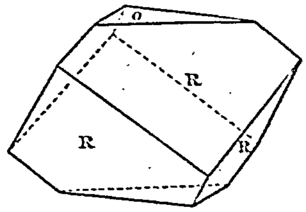


Fig. 405 (sp. 343).

344. JAROSITE, $\dot{K}_2\dddot{S}+\ddot{F}e_2 3\dddot{S}+2(\ddot{F}e_2 3\dot{H}_2)$.

Rhombohedral; R 88° 58′. Cl. basal; also fibrous in nodules or incrusting. H. = 2·5 to 3·5; G. = 3·24. Colour ochre-yellow. Spain, Saxony, and Mexico.

345. GELBEISENERZ, $\dot{K}_2\dddot{S}+4\ddot{F}e_2\dddot{S}+9\dot{H}_2$.

Foliated and massive. H. = 2·5 to 3; G. = 2·7 to 2·9. Bohemia, Norway, and Tcheleken Island in the Caspian Sea.

346. URUSITE, $\ddot{F}e_2\dddot{S}+2\dot{N}a_2 3\dddot{S}+8\dot{H}_2$.

Tcheleken Island in the Caspian.

347. BOTRYOGENE (*Red Vitriol*), $\dot{F}e_3\dddot{S}_2+3(\ddot{F}e_2 2\dddot{S})+36\dot{H}_2$.

Oblique prismatic, C 62° 26′. ∞P 119° 56′. Commonly botryoidal. H. = 2 to 2·5; G. = 2. Translucent; vitreous. Hyacinth-red and orange-yellow. Falun in Sweden.

348. HERRENGRUNDITE.

Oblique prismatic, C 88° 50′. Dark emerald-green crystals. H. = 2·5; G. = 3·13. C.c.: 57·22 oxide of copper, 23·04 sulphuric oxide, 19·44 water, sometimes with lime. Herrengrund (Hungary).

349. LINARITE, $(\dot{P}b\dddot{S}+\dot{H}_2\dot{P}b)+(\dot{C}u\dddot{S}+\dot{H}_2\dot{C}u)$.

Oblique prismatic, C 77° 22′. ∞P (*M*) 61° 41′; $2P^{o}\infty$ (*u*) 52° 31′. Crystals $\infty P^{o}\infty$ (*a*), 0P (*c*), and the above forms generally. Hemitropes united by $\infty P^{o}\infty$ (*a*). Cl. orthodiagonal, perfect; fracture

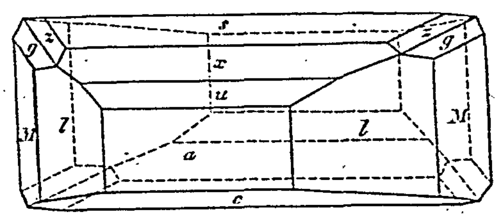


Fig. 406.

conchoidal. H. = 2·5 to 3; G. = 5·2 to 5·45. Translucent; adamantine. Azure-blue to dark blue; streak pale blue. C.c.: oxide of lead 55·69, oxide of copper 19·83, sulphuric acid 19·98, water 4·5. Leadhills, Red Gill and Roughton Gill (Cumberland), Linares in Spain, and Nertchinsk.

350. CALEDONITE, $5\dot{P}b\dddot{S}+2(\dot{H}_2\dot{P}b)+3(\dot{H}_2\dot{C}u)$.

Right prismatic. ∞P (*m*) 95°; $\breve{P}\infty$ (*c*) 70° 57′; $2\bar{P}\infty$ (*x*) 36° 10′. Crystals frequently as in fig. 407, but generally hemihedral. Cl. brachydiagonal, *a* distinct; *m*, *c* imperfect. H. = 2·5 to 3; G. = 6·4. Transparent; resinous. Verdigris-green and mountain-green; streak greenish white. C.c.: 68·42 oxide of lead, 10·17 oxide of copper, 17·3 sulphuric acid, 4·05 water. Leadhills, Red Gill in Cumberland, Rezbanya in Transylvania.

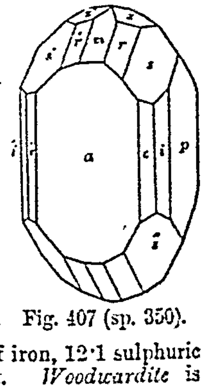


Fig. 407 (sp. 350).

351. LETTSOMITE, $3\dot{C}u_3\dddot{S}+2(\ddot{A}l_2 3\dot{H}_2)+15\dot{H}_2$.

Right prismatic; but in tufts of capillary crystals with velvet-like appearance. Colour smalt-blue to sky-blue. C.c.: 49 oxide of copper, 2·97 lime, 11·21 alumina, 1·41 oxide of iron, 12·1 sulphuric acid, 22·5 water. Moldawa in the Banat. *Woodwardite* is probably an aluminous variety of the above. Turquoise-blue to greenish blue. Cornwall.

352. KAINITE, $\dot{M}g\dddot{S}+KCl+3\dot{H}_2$.

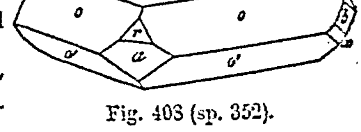


Fig. 408 (sp. 352).

Oblique prismatic, C 85° 5′ (fig. 408). G. = 2·13. Cl. orthodiagonal. White to reddish. C.c.: 16·1 magnesia, 15·7 potash, 32·2 sulphuric acid, 14·3 chlorine, 21·7 water. Stassfurt.

TELLURATES AND CHROMATES.

353. MONTANITE, $\ddot{B}i_2\dddot{T}e + 2\dot{H}_2$.

Incrusting, earthy. Lustre waxy. Yellowish. Opaque. C.c. bismuth 66·8, tellurium 26·8, water 5·9. Highland in Montana.

354. MAGNOLITE, $\dot{H}g\dddot{T}e$.

White acicular crystals from Keystone mine in Colorado.

355. CROCOISITE, $\dot{P}b\dddot{C}r$.

Oblique prismatic, C 77° 27′. ∞P 93° 42′ (*M*), − P 119° 12′ (*t*), ∞P^c^2 (*f*) 56° 10′, ∞P^c^∞ (*g*), (fig. 409). Cl. ∞P, distinct; sectile. H. = 2·5 to 3; G. = 5·9 to 6·1. Translucent; adamantine. Hyacinth- or aurora-red; streak orange-yellow. C.c.: 31 chromic acid, and 69 lead protoxide. Berezoff, Mursinsk, and Nijni-Tagilsk in the Urals, Congonhas do Campo in Brazil, Rezbanya, Moldawa, and Tarnowitz. Used as a pigment, but not permanent.

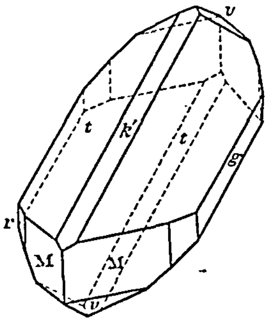


Fig. 409 (sp. 355).

356. PHŒNICO-CHROITE, $2\dot{P}b\dddot{C}r + \dot{P}b$.

Right prismatic; dimensions unknown. H. = 3 to 3·5; G. = 5·75. Translucent on the edges; resinous or adamantine. Cochineal- to hyacinth-red; streak brick-red. C.c.: 23 chromic acid, and 77 protoxide of lead. Berezoff.

357. VAUQUELINITE, $2(2\dot{P}b\dddot{C}r + \dot{P}b) + (2\dot{C}u\dddot{C}r + \dot{C}u)$.

Oblique prismatic, C 67° 15′. Crystals 0P, − P, − P^o^∞ (or *P*, *f*, *h*), always twinned (fig. 410), the faces of 0P forming an angle of 134° 30′; also botryoidal or reniform. H. = 2·5 to 3; G. = 5·5 to 5·8. Semi-translucent or opaque; resinous. Blackish or dark olive-green; streak siskin-green. C.c.: 61 lead protoxide, 11 copper protoxide, 28 chromic acid. Leadhills, Berezoff, Congonhas do Campo (Brazil).

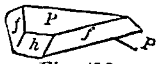


Fig. 410.

MOLYBDATES AND TUNGSTATES.

358. WULFENITE, $\dot{P}b\dddot{M}o$.

Pyramidal. P 131° 48′. 0P (*a*), ⅓P (*b*), P, ∞P (*m*), ∞P2 (*r*) (figs. 411–414). Cl. P; brittle; fracture uneven, or conchoidal. H. = 3; G. = 6·3 to 6·9. Pellucid; resinous to adamantine. Orange-yellow, honey-yellow, and colourless. C.c.: protoxide of lead 61·5, molybdic acid 38·5; red varieties have some chromic acid. Lackentyre in Kirkcudbright (fig. 412), Bleiberg, Rezbanya, Pennsylvania, Zacatecas. $2PbOMoO_3$ + $CaOMoO_3$, with 6·88 of lime, occurs in Chili.

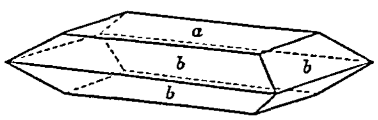


Fig. 411.

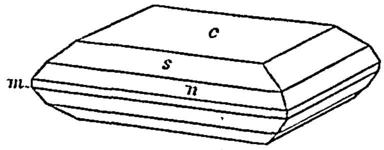


Fig. 412.

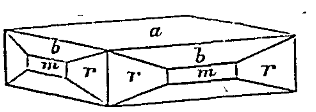


Fig. 413 (sp. 358).

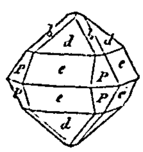


Fig. 414 (sp. 358).

359. EOSITE.

Pyramidal. 0P (*c*) : *p′* 117° 10′; *p′* : *p* 125° 40′ (fig. 415). H. = 3 to 4. Colour deep aurora-red. Streak orange-yellow. A vanadio-molybdate of lead. Leadhills.

360. MEGABASITE, $\dot{M}g_4\dddot{W}_3$.

Oblique prismatic; similar to wolframite. In fine needles. H. = 3·5 to 4; G. = 6·45 to 6·97. Vitreous to adamantine. Yellowish brown to brownish red, translucent hyacinth-red; streak ochre-yellow. C.c.: protoxide of manganese 23·1, protoxide of iron 5·4, tungstic acid 71·5. Schlaggenwald, Sadisdorf, Morococha in Peru.

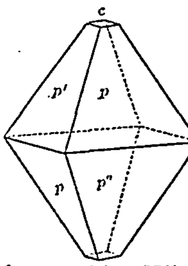


Fig. 415 (sp. 359).

361. SCHEELITE, $\dot{C}a\dddot{W}$.

Pyramidal; with many of the modifying planes hemihedric. P. 113° 32′. Cl. 2P∞ (*n*) 130° 33′, perfect; P and 0P less so. Fracture conchoidal. H. = 4 to 4·5; G. = 5·9 to 6·2. Translucent; resinous to adamantine. Colourless, and grey, yellow, or brown; streak white. C.c.: 19·4 lime, 80·6 tungstic acid. Caldbeckfell near Keswick, Pengelly in Cornwall, Zinnwald, Schlaggenwald, Salzburg, Chili, Siberia, Connecticut. Employed for the extraction of yellow tungstic acid, a fine pigment.

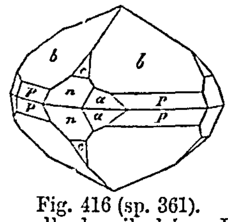


Fig. 416 (sp. 361).

362. STOLZITE, $\dot{P}b\dddot{W}$.

Pyramidal, generally hemihedric. P. 131° 25′. Crystals sometimes spindle-shaped. Cl. P, imperfect. H. = 3; G. = 7·9 to 8·1. Translucent; resinous. Grey, yellow, brown. C.c.: 48·4 protoxide of lead, 51·6 tungstic acid. Keswick, Zinnwald, Coquimbo (Brazil).

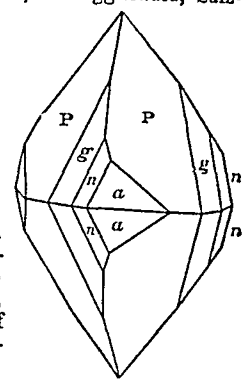


Fig. 417 (sp. 361).

363. REINITE, $\dot{F}e\dddot{W}$.

Pyramidal. P 103° 32′; basal angle 122° 8′. Cl. ∞P. H. = 4; G. = 6·64. C.c.: protoxide of iron 23·4, tungstic acid 75·45. Kimbosan in Japan.

364. WOLFRAMITE, $(\dot{F}e, \dot{M}n)\dddot{W}$.

Oblique prismatic, C 89° 22′. ∞P (*M*) 100° 37′, − ½P^o^∞ (*P*) 61° 54′, P^c^∞ (*u*) 98° 6′, ∞P∞ (*r*), ∞P^o^2 (*b*), − P (*a*), ½2P^c^2(*s*). Twins common. Also laminar. Cl. clinodiagonal, perfect; fracture uneven. H. = 5 to 5·5; G. = 7·1 to 7·5. Opaque; resinous, metallic, adamantine on the cleavage. Brownish black; streak black (varieties with most iron) to reddish brown (most manganese). C.c.: 76 tungstic acid, 9·5 to 20 protoxide of iron, and 4 to 15 protoxide of manganese, in some with 1·1 niobic acid. East Pool, Carnbrae, and mines near Redruth; Godolphin's Ball in Cumberland; Altenberg, Geyer, Ehrenfriedersdorf, Schlaggenwald, Zinnwald, the Harz; also Urals, Ceylon, and North America. *Ferberite*, with 26 protoxide of iron and $2\dot{F}e\dddot{W} + \dot{F}e$ (H. = 4 to 4·5; G. = 6·7 to 6·8), from Spain, may be different.

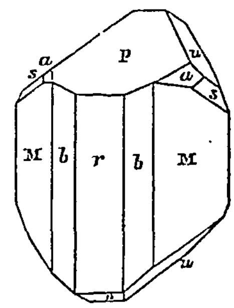


Fig. 418.

365. HÜBNERITE, $\dot{M}n\dddot{W}$.

Right prismatic. ∞P (*M*). *M* : *M* 105°. Cl. ∞P̆∞, perfect; usually foliated or columnar. H. = 4·5; G. = 7·14. Adamantine on cleavage; elsewhere greasy. Brown-red; streak yellow-brown. C.c.: protoxide of manganese 23·4, tungstic acid 76·6. Mammoth district in Nevada.

ANHYDROUS PHOSPHATES, ARSENIATES, AND VANADIATES.

366. XENOTIME, $\dot{Y}_3\dddot{\dot{P}}$.

Pyramidal. P 82° 22′ middle angle; polar angle 124° 30′. Crystals P; ∞P; ∞P∞. Cl. ∞P. H. = 4·5; G. = 4·6 to 4·55. Translucent in thin splinters; resinous. Yellowish and flesh-red. C.c.: 62 yttria, and 38 phosphoric acid; but some with 8 to 11 cerium protoxide. Lindesnaes and Hitterö in Norway, Ytterby (Sweden), Georgia, and (*Wiserine*) St Gotthard.

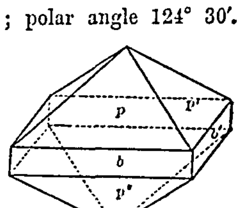


Fig. 419 (sp. 366).

367. CRYPTOLITE, $\dot{C}e_3\dddot{\dot{P}}_2$.

Acicular crystals, embedded in apatite. G. = 4·6. Transparent. Pale wine-yellow. Powder sol. in con. s. acid. Wöhler found 73·70 cerium protoxide, 27·37 phosphoric acid, and 1·51 iron protoxide. Occurs in the apatites of granite in Scotland, but not in those of limestones. Also at Arendal.

368. MONAZITE, $(\dot{C}e, \dot{L}a, \ddot{T}h)_3\dddot{\dot{P}}_2$.

Oblique prismatic, C 76° 14′. ∞P 93° 23′; crystals (fig. 420) generally thick or tabular. Cl. basal, perfect; translucent on edges. Flesh-red and reddish brown. C.c.: 28 phosphoric acid, 37 to 46 cerium protoxide, 24 to 27 lanthanum oxide; that from Zlatoust from 18 to 32·5 of thoria. Nöterö in Norway, Miask, Norwich in Connecticut, and the Rio Chico in Colombia. *Turnerite*, from Dauphiné, in complex transparent honey-yellow crystals, is monazite.

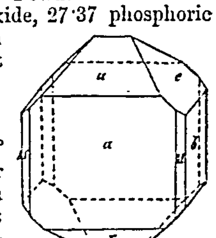


Fig. 420 (sp. 368).

369. TRIPHYLITE, $(2\dot{F}e+\dot{L}i_2)\dddot{P}_2$.
Right prismatic. ∞P 133°; chiefly granular. H. = 5; G. = 3·6. Resinous. Greenish grey with blue spots. C.c.: iron protoxide 40, manganese protoxide 5·5, lithia 7·5, phosphoric acid 45. Bodenmais in Bavaria, Norwich in Massachusetts. *Lithiophilite*, from Fairfield (Connecticut), is a manganesian triphylite.

370. BERZELIITE (*Kuhnite*), $(\dot{C}a\dot{M}g)_3\dddot{A}s_2$.
Massive. H. = 5 to 6; G. = 2·52. C.c.: lime 23, magnesia 15, arsenic acid 60. Sol. in n. acid. Långban (Sweden).

371. ARSENIATE OF NICKEL, $\dot{N}i_3\dddot{A}s_2$.
Amorphous. H. = 4; G. = 4·98. Sulphur-yellow. C.c.: oxide of nickel 48·2, arsenic acid 50·5. Johann-Georgenstadt.

372. NICKELERZ, $\dot{N}i_3\dddot{A}s_2+2\dot{N}i$.
Crystalline massive. G. = 4·84. Dark grass-green; streak lighter. C.c.: oxide of nickel 62·1, arsenic acid 36·6. Johann-Georgenstadt.

373. DECHENITE, $(\dot{P}b\dot{Z}n)\dddot{V}_2$.
Botryoidal and stalactitic. H. = 3 to 4; G. = 5·82. Lustre resinous to greasy. Yellowish red, deep red; streak orange to pale yellow. C.c.: 57·7 oxide of lead, 15·8 oxide of zinc, 24·2 of vanadic acid. Wanlockhead, Freiburg (in Baden), Lauter Valley.

374. PSITTACINITE, $3(\dot{P}b_3\dddot{V}_2)+\dot{C}u_3\dddot{V}_2+6\dot{C}u\dot{H}_2$.
Mammillated and incrusting. Siskin- to olive-green. C.c.: vanadic acid 19·3, lead oxide 53·2, copper oxide 18·95, water 8·58. Silver Star (Montana).

375. PUCHERITE, $\dddot{B}i_2\dddot{V}_2$.
Right prismatic. ∞P 123° 55′. H. = 4; G. = 6·25. Cl. basal, perfect; vitreous. Red or reddish brown; streak yellow. Easily soluble in acids. C.c.: bismuth oxide 71·7, vanadic acid 28·3. Schneeberg.

376. ATOPITE, $\dot{C}a_3\dddot{S}b_2$.
Cubic (figs. 30 with 26 and 33). H. = 5·5 to 6; G. = 5. Lustre greasy; yellow to resin-brown. Translucent. C.c.: antimonic acid 73·2, lime 17·5, iron protoxide 2·7, magnesia 1·5, soda 4·3. Långban (Wermland).

HYDROUS PHOSPHATES, &c.

377. BRUSHITE, $(\frac{2}{3}\dot{C}a+\frac{1}{3}\dot{H}_2)_3\dddot{P}_2+4\dot{H}_2$.
Oblique prismatic, C 62° 45′. Needle crystals. H. = 2 to 2·5; G. = 2·21. Vitreous. C.c.: lime 32·6, phosphoric acid 41·3, water 26·4. Aves Islands and Sombrero (Antilles).

378. NEWBERYITE, $\dot{M}g_2\dot{H}_2,\ \dddot{P}_2+6\dot{H}_2$.
Right prismatic. Cl. brachydiagonal. C.c.: phosphoric acid 41·25, magnesia 23, water 35·7. From guano, Skipton Caves, Victoria.

379. HAIDINGERITE. $\dot{C}a_2\dddot{A}s_2+3\dot{H}_2$.
Right prismatic. ∞P 100°. Cl. perfect; sectile, flexible. H. = 2 to 2·5; G. = 2·8 to 2·9. Otherwise like pharmacolite (sp. 381). C.c.: 85·68 arseniate of lime, and 14·32 water. Joachimsthal.

380. ROSELITE, $\dot{R}_3\dddot{A}s_2+2\dot{H}_2$.
Anorthic. Cl. macrodiagonal. Rose-red; streak white. H. = 3·5; G. = 3·46. C.c.: 25·5 lime, 10·3 cobalt oxide, 3·6 magnesia, 52·4 arsenic acid, 8·2 water. Schneeberg.

381. PHARMACOLITE, $2\dot{C}a\dddot{A}s_2+6\dot{H}_2$.
Oblique prismatic, C 65° 4′ (fig. 421). ∞P (f) 117° 24′, $-P$ (l) 139° 17′, $-\frac{1}{2}P$ (n) 141° 8′, $\frac{1}{2}P^o\infty$ (o) 83° 14′, ∞P^o3 (g) 157° 5′. Crystals generally acicular and radiated. Cl. clinodiagonal, perfect; sectile and flexible. H. = 2 to 2·5; G. = 2·6 to 2·8. Translucent; vitreous. Pearly white. Yields water in the closed tube. C.c.: arsenic acid 51, lime 25, water 24. Andreasberg, Bieber, Markirchen, Wittichen. Generally mixed with erythrite or annabergite.

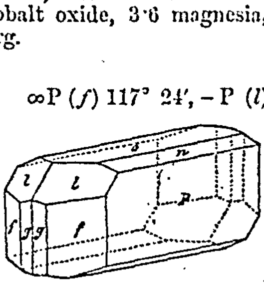


Fig. 421.

382. WAPPLERITE, $2\dot{C}a\dddot{A}s+8\dot{H}_2$.
Anorthic; $\infty P'$ (m), $\infty'P$ (M), $\infty\bar{P}'2$ (n), $\infty'\bar{P}.2$ (N), $,\bar{P}'\infty$ (d), $'P,\infty$ (D), $3,\breve{P}'\infty$ (t), $3'\breve{P},\infty$ (T), $2\bar{P}'2$ (p), $3\breve{P}'\frac{3}{2}$ (g), $3'\breve{P}\frac{3}{2}$ (G), $4,\bar{P}4$ (ω), $2,\bar{P}2$ (π), $\infty\breve{P}\infty$ (b) (fig. 422); also incrusting and globular. Cl. clinodiagonal. H. = 2 to 2·5; G. = 2·48. Colourless. Vitreous. C.c.: lime 15·6, magnesia 7·4, arsenic acid 47·5, water 29·5. Joachimsthal.

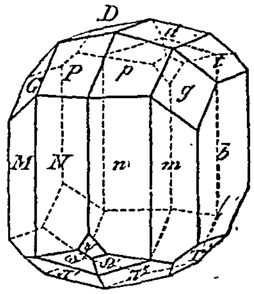


Fig. 422 (sp. 382).

383. HÖRNESITE, $\dot{M}g_3\dddot{A}s_2+8\dot{H}_2$.
Oblique prismatic. ∞P 107°. H. = 5 to 1; G. = 2·47. White. Translucent; pearly. C.c.: 24·3 magnesia, 29·14 water, 46·56 arsenic acid. Probably from Hungary.

384. VIVIANITE, $3\dot{F}e\dddot{P}_2+8\dot{H}_2$.
Oblique prismatic, C 75° 34′. ∞P (m) 108° 2′; P (v) 120° 26′, $P^o\infty$ (w) 54° 40′. Crystals prismatic (figs. 423, 424); also fibrous or earthy. Cl. clinodiagonal, perfect; thin laminæ flexible. H. = 2; G. = 2·6 to 2·7. Translucent or transparent; vitreous, or bright pearly on cleavage. Indigo-blue to blackish green; streak bluish white, but soon becomes blue on exposure. C.c.: 33·1 iron protoxide, 12·2 iron peroxide, 29 phosphoric acid, and 25·7 water. Transparent indigo-coloured crystals at St Agnes in Cornwall, and Allentown and Imleytown in New Jersey; earthy in Cornwall, Styria, North America, Greenland, and New Zealand; and in peat mosses in northern Germany, Sweden, Norway, and Shetland.

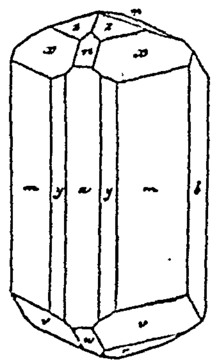


Fig. 423.

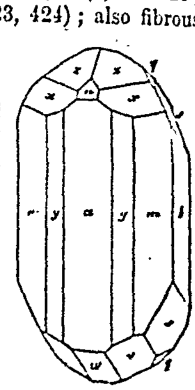


Fig. 424.

385. SYMPLESITE, $\dot{F}e_3\dddot{A}s_2+8\dot{H}_2$.
Oblique prismatic; in minute acicular crystals. Cl. clinodiagonal. H. = 2·5; G. = 2·96. Vitreous. Cleavage face pearly. Celadon-green to pale indigo; streak bluish white. Lobenstein in Reuss, and Lölling in Carinthia.

386. ERYTHRITE, $\dot{C}o_3\dddot{A}s_2+8\dot{H}_2$.
Oblique prismatic, C 55° 9′. $\infty P^c\infty$ (P), $\infty P^o\infty$ (T), $P\infty$ (M); also $\infty P3$ (k), and P (l) 118° 23′ (fig. 425). Cl. clinodiagonal (P), perfect; sectile; thin laminæ flexible. H. = 1·5 to 2·5; G. = 2·9 to 3. Translucent; vitreous, pearly on the cleavage. Crimson or peachblossom-red. C.c.: 38·2 arsenic acid, 37·8 cobalt protoxide, 24 water, but often with nickel 9. Cornwall, Alston in Cumberland, Alva in Stirlingshire, Schneeberg, Saalfeld, Allemont, Riechelsdorf, the Pyrenees, and Modum in Norway. *Kobaltbeschlag* or *Earthy Incrusting Cobalt*, reniform, is a mixture of erythrine with arsenious acid. *Lavendulan*, thin reniform lavender-blue crusts, translucent, resinous, or vitreous (H. = 2·5 to 3; G. = 2·95 to 3·1), consisting of arsenic acid, protoxides of cobalt, nickel, and copper, with water; from Annaberg.

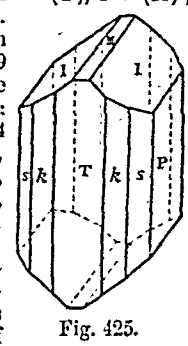


Fig. 425.

387. KÖTTIGITE, $(\dot{Z}n,\ \dot{C}o,\ \dot{N}i)_3\dddot{A}s_2+8\dot{H}_2$.
Oblique prismatic; massive or in crusts, with crystalline surface and fibrous structure. Cl. clinodiagonal, perfect. H. = 2·5 to 3; G. = 3·1. Lustre of fracture silky. Colour light carmine and peach-blossom-red, of different shades; streak reddish white. Translucent to subtranslucent. C.c.: 30·52 zinc oxide, 6·91 cobalt oxide, 2 nickel oxide, with arsenic acid. Schneeberg.

388. ANNABERGITE (*Nickel Ochre*), $\dot{N}i_3\dddot{A}s+8\dot{H}_2$.
Oblique prismatic; in capillary crystals, also earthy; sectile. H. = 2 to 2·5; G. = 3 to 3·1. Dull or glistening. Apple-green or greenish white; streak greenish white and shining. C.c.: 38·7 arsenic acid, 37·3 nickel protoxide, and 24 water, but with a little cobalt or iron. Leadhills, Pibble in Kirkcudbright, Andreasberg, Saalfeld, Riechelsdorf.

389. LUDLAMITE, $\dot{F}e_7 2\dddot{P}_2+9\dot{H}_2$.
Oblique prismatic, C 79° 27′. ∞P 131° 23′; 0P; P 111° 29′ (fig. 426). Cl. 0P, perfect. H. = 3·5; G. = 3·12. C.c.: 53·05 oxide of iron, 29·88 phosphoric acid, 17·0 water. Cornwall.

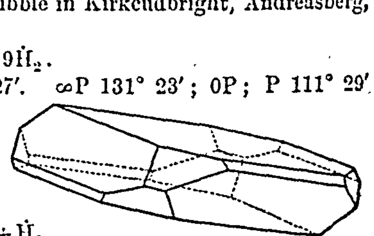


Fig. 426 (sp. 389).

390. FILLOWITE, $3(\dot{R}_3\dddot{P}_2)+\dot{H}_2$.
Oblique prismatic, C 89° 51′; pseudo-rhombohedral. P; $-2\bar{P}8$; 0P. Cl. basal. H. = 4·5; G. = 3·43. Resinous to greasy. Wax-yellow to red-brown, or colourless; streak white; translucent. C.c.: phosphoric acid 40·2, iron protoxide 6·8, manganese protoxide 40·2, lime 5·2, soda 5·8, water 1·7. Branchville (Connecticut).

391. HUREAULITE, $5(\dot{M}n,\ \dot{F}e)2\dddot{P}_2+5\dot{H}_2$.
Oblique prismatic, C 89° 27′. ∞P 61°. Fracture conchoidal. H. = 3·5; G. = 3·2. Translucent; resinous. Reddish yellow or brown. B.B. fuses easily to a black metallic globule. Soluble in acids. C.c.: 39 phosphoric acid, 8 iron protoxide, 42 manganese protoxide, and 12 water. Hureaux near Limoges.

Heterozite. H. = 5; G. = 3·5. Opaque; vitreous or resinous. Dark violet or blue to greenish grey; streak violet-blue or crimson-red. Contains more iron and less manganese than the above. Hureaux.

392. DICKINSONITE, $4(\dot{R}_3\dddot{\bar{P}}_2)+3\dot{H}_2$.
Oblique prismatic, C 60° 30′. Crystals tabular. Cl. basal, perfect. H. = 3·5 to 4; G. = 3·34. Vitreous; pearly on cleavage. Olive- to oil-green, and grass-green; streak white. Transparent; brittle. C.c.: phosphoric acid 40, iron protoxide 12·7, manganese protoxide 25, lime 11·8, soda 6·6, water 3·8. Branchville (Connecticut).

393. TRIPLOIDITE, $(\dot{M}n, \dot{F}e)_3\dddot{\bar{P}}_2+\dot{H}_2(\dot{M}n, \dot{F}e)_2$.
Oblique prismatic, C 51° 56′. Generally fibrous; transparent; resinous to adamantine. H. = 4·5 to 5; G. = 3·7. Yellowish-brown. C.c.: 48·45 oxide of manganese, 14·88 protoxide of iron, 32·1 phosphoric acid, 4·1 water. Fairfield (Connecticut).

394. FAIRFIELDITE, $\dot{R}_3\dddot{\bar{P}}_2+2\dot{H}_2$.
Anorthic; usually foliaceous. H. = 3·5; G. = 3·15. White to straw-yellow; streak white. Pearly to brilliant-adamantine on cleavage. Transparent; brittle. C.c.: phosphoric acid 38·4, iron protoxide 5·6, manganese protoxide 15·6, lime 30, soda ·7, water 10. Fairfield (Connecticut).

395. CHONDRARSENITE, $\dot{M}n_5\dddot{\bar{A}}s_2+\frac{5}{2}\dot{H}_2$.
In small grains. H. = 3. Yellow to reddish-yellow. Translucent; brittle; fracture conchoidal. Paisberg mines (Wermland).

396. REDDINGITE, $\dot{M}n_3\dddot{\bar{P}}_2+3\dot{H}_2$.
Right prismatic. P; $\breve{P}2$; $\infty\breve{P}\infty$. H. = 3 to 3·5; G. = 3·1. Vitreous; rose-pink to yellowish white. Translucent; fracture uneven; brittle. C.c.: phosphoric acid 34·5, iron protoxide 5·43, manganese protoxide 46·3, lime ·8, water 13·1. Branchville.

397. SCORODITE, $\ddot{\bar{F}}e_2\dddot{\bar{A}}s_2+4\dot{H}_2$.
Right prismatic. P with polar edges 102° 52′ and 114° 40′. Crystals P (*p*), $\infty\bar{P}\infty$ (*a*), and $\infty\breve{P}\infty$ (*b*); also 0P, $\frac{1}{2}$P (*i*), ∞P (*n*), $2\breve{P}2$ (*s*), $\infty\breve{P}2$ (*d*) 120° 10′, and $2\bar{P}\infty$ (*m*) 132° (fig. 427); also columnar and fibrous. Cl. imperfect; brittle. H. = 3·5 to 4; G. = 3·1 to 3·2. Translucent; vitreous. Leek-green to greenish black, also indigo-blue, red, and brown. B.B. fuses easily, with arsenical odour, to a grey magnetic slag. Sol. in h. acid, to a brown solution. C.c.: 49·8 arsenic acid, 34·6 iron peroxide, and 15·6 water. St Austell in Cornwall, near Limoges in France, Schwarzenberg, Lölling in Carinthia, Brazil, and Siberia.

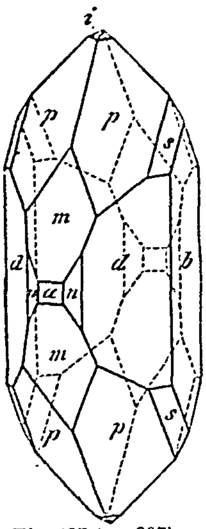


Fig. 427 (sp. 397).

398. STRENGITE, $\ddot{\bar{F}}e_2\dddot{\bar{P}}_2+4\dot{H}_2$.
Right prismatic. P with polar edges 101° 38′ and 115° 36′, middle edge 111° 30′. $\infty\breve{P}2$ (*d*) and $\infty\bar{P}\infty$ (*r*), P (*P*), 0P (*h*), $2\bar{P}\infty$ (*m*) 48° (fig. 428). Crystals generally *r*, *P*, *d*; *r* dominant. Cl. *r*. H. = 3 to 4; G. = 2·87. Cherry-red. Translucent. C.c.: protoxide of iron 43·18, phosphoric acid 37·42, water 19·4. Rock Bridge (Virginia).

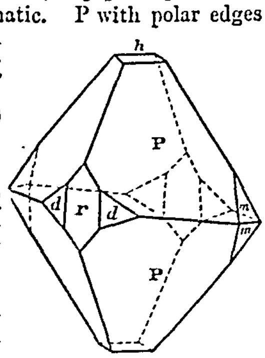


Fig. 428 (sp. 398).

399. DUFRENITE (*Kraurite*), $2\ddot{\bar{F}}e_2\dddot{\bar{P}}_2+3\dot{H}_2$.
Right prismatic. ∞P about 123°. Spherical or reniform. Cl. brachydiagonal; brittle. H. = 3 to 3·5; G. = 3·3 to 3·4. Translucent on the edges, or opaque; shining or dull. Dirty leek-green or blackish green; streak siskin-green. C.c.: 63 iron peroxide, 28 phosphoric acid, and 9 water. Westerwald, Hirschberg, and Limoges.

400 BERAUNITE, $5\ddot{\bar{F}}e_23\dddot{\bar{P}}_2+14\dot{H}_2$.
Occurs in small foliated and columnar aggregates. Cl. plane metallic pearly. H. = 2; G. = 2·878. Colour hyacinth-red to reddish brown; streak dirty-yellow. C.c.: 54·5 peroxide of iron, 28·65 phosphoric acid, and 16·55 water. Bohemia, Scheibenberg in Saxony.

401. ELEONORITE, $3\ddot{\bar{F}}e_22\dddot{\bar{P}}_2+8\dot{H}_2$.
Oblique prismatic, C 48° 33′. Twin face the orthopinacoid. Cl. $\infty P°\infty$. H. = 3 to 4. Dark hyacinth-red; streak yellow. Vitreous to pearly. C.c.: 51·94 peroxide of iron, 31·88 phosphoric acid, 16·37 water. Eleonore mine near Bieber.

402. CACOXENE, $2\ddot{\bar{F}}e_2\dddot{\bar{P}}_2+12\dot{H}_2$.
Radiated tufts, of a brownish-yellow colour. H. = 3 to 4; G. = 3·38. Sol. in h. acid. From the Hrbeck mine near Zbirow in Bohemia.

403. PHARMACOSIDERITE (*Cube Ore*), $4\ddot{\bar{F}}e_23\dddot{\bar{A}}s_2+15\dot{H}_2$.
Cubic and tetrahedral; usually $\infty O\infty$, with $\frac{O}{2}$, or ∞O. Brittle. H. = 2·5; G. = 2·9 to 3. Cl. $\infty O\infty$. Semitransparent to translucent; adamantine or resinous. Olive- to emerald-green, honey-yellow, and brown; streak straw-yellow. Pyro-electric. C.c.: 43 arsenic acid, 40 iron peroxide, and 17 water. Carharrack in Cornwall, Burdle Gill in Cumberland, Lobenstein in Reuss, Schwarzenberg in Saxony, North America, and the gold quartz of Australia.

404. CALAITE (*Turquoise*), $2(\ddot{\bar{A}}l_2)\dddot{\bar{P}}_2+5\dot{H}_2$.
Massive, reniform, or stalactitic; fracture conchoidal. H. = 6; G. = 2·6 to 2·8. Opaque or translucent on the edges; dull or waxy. Sky-blue, greenish blue, rarely green; streak greenish white. C.c.: 47 alumina, 32·5 phosphoric acid, and 20·5 water, but mixed with phosphate of iron and copper. Silesia, Lusatia, and Reuss. Oriental turquoise, in veins, at Meshed, near Herat; in pebbles in Khorasan, Bokhara, and Syrian desert. Takes a fine polish, and is valued as an ornamental stone, but is destroyed by oil, and deteriorated by soap.

405. WAVELLITE (*Lasionite*), $3\ddot{\bar{A}}l_22\dddot{\bar{P}}_2+12\dot{H}_2$.
Right prismatic. ∞P 126° 25; $\bar{P}\infty$ 106° 46′. Crystals $\infty P\infty$ (*P*), ∞P (*d*), $\bar{P}\infty$ (*o*) (fig. 429); but generally small, acicular, and in radiated-hemispherical and stellate-fibrous masses. Cl. along ∞P and $\bar{P}\infty$, perfect. H. = 3·5 to 4; G. = 2·3 to 2·5. Translucent; vitreous. Colourless, but generally yellowish or greyish, sometimes green or blue. C.c.: 38 alumina, 35·3 phosphoric acid, and 26·7 water; but generally traces of fluoric acid (2 per cent.). Shiant Islands and Glencoe in Scotland, Barnstaple, St Austell, near Clonmel and Portrush, Beraun in Bohemia, Amberg in Bavaria; also in New Hampshire and Tennessee. *Cæruleolactin*, from Nassau, has two equivalents less of water.

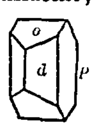


Fig. 429.

406. VARISCITE, $\ddot{\bar{A}}l_2\dddot{\bar{P}}_2+4\dot{H}_2$.
Right prismatic; reniform; conchoidal fracture. H. = 4 to 5; G. = 2·34 to 2·38. Apple- and emerald-green; streak white. C.c.: 32·4 alumina, 44·85 phosphoric acid, 22·74 water. Messbach in Reuss, Montgomery county in Arkansas.
Zepharovichite from Bohemia contains one equivalent more water; *Evansite* from Hungary two equivalents more.

407. FISCHERITE, $2\ddot{\bar{A}}l_2\dddot{\bar{P}}_2+8\dot{H}_2$.
Right prismatic. ∞P 118° 32′; generally in crystalline crusts. H. = 5; G. = 2·46. Grass- and olive-green. Vitreous lustre. C.c.: alumina 42, phosphoric acid 29, water 29. Nijni-Tagilsk.

408. PEGANITE, $2\ddot{\bar{A}}l_2\dddot{\bar{P}}_2+6\dot{H}_2$.
Right prismatic. ∞P 127°. In thin reniform crusts, of fibrous structure. H. = 3 to 4; G. = 2·49 to 2·54. Grass- and emerald-green. Vitreous or greasy lustre. C.c.: alumina 45, phosphoric acid 31·3, water 23·7. Striegis in Saxony.

409. HOPEITE, $\dot{Z}n_3\dddot{\bar{P}}+4\dot{H}_2$.
Right prismatic. $\infty\breve{P}2$ 82° 20′; P with polar edges 106° 36′ and 140°. Cl. macrodiagonal, perfect. H. = 2·5 to 3; G. = 2·76 to 2·85. Vitreous or pearly. Greyish white. C.c.: oxide of zinc 35·21, phosphoric acid 31·1, water 15·8. Altenberg.

410. ADAMITE, $4\dot{Z}n\dddot{\bar{A}}s_2+\dot{H}_2$.
Right prismatic. ∞P 91° 52′. Cl. macrodomic. H. = 3·5; G. = 4·34. Lustre vitreous. Colour honey-yellow to violet; streak white. Transparent. C.c.: oxide of zinc 56·6, arsenic acid 40·2, water 3·2. Cape Garonne in France, Chañarcillo in Chili.

411. LIBETHENITE $4\dot{C}u\dddot{\bar{P}}_2+6\dot{H}_2$.
Right prismatic. ∞P (*u*) 92° 20′, $\breve{P}\infty$ (*o*) 109° 52′, and P (fig. 430). H. = 4; G. = 3·6 to 3·8. Translucent on the edges; resinous. Leek-, olive-, or blackish-green; streak olive-green. C.c.: 66 copper protoxide, 30 phosphoric acid, and 4 water. Gunnislake (Devon), Libethen (Hungary), Nijni-Tagilsk.

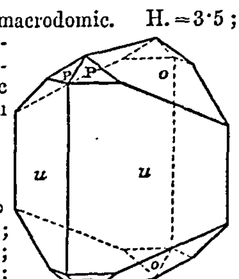


Fig. 430 (sp. 411).

412. Olivenite, $4\dot{C}u\,(\dddot{A}s_2\dddot{P}_2)+\dot{H}_2$.

Right prismatic. $\infty(P)$ (*r*) 92° 30′, $\breve{P}\infty$ (*l*) 110° 50′, $\infty\bar{P}\infty$ (*n*) (fig. 431); also spherical and reniform, and columnar or fibrous. Cl. (*r*) and (*l*), imperfect. H. = 3; G. = 4·1 to 4·6. Pellucid in all degrees; vitreous, resinous, or silky. Leek-, olive-, or blackish-green, also yellow or brown; streak olive-green or brown. B.B. in the forceps fuses easily to a dark brown adamantine bead, covered with radiating crystals; on charcoal detonates, emits arsenical vapours, and is reduced. Sol. in acids and ammonia. C.c.: 56·5 copper protoxide, 39·5 arsenic acid, and 4 water; but also 1 to 6 phosphoric acid. Carharrack, Tin Croft, Gwennap, and St Day in Cornwall; Alston Moor, Thuringia, Tyrol, Siberia, Chili.

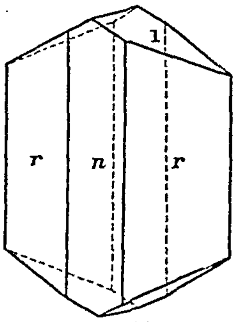


Fig. 431.

413. Veszelyite, $9\dot{C}u$, $6\dot{Z}n$, $\dddot{P}_2$, $\dddot{A}s_2+18\dot{H}_2$.

Oblique prismatic, C 103° 50′. H. = 3·5 to 4; G. = 3·53. Greenish blue. C.c.: copper 37·34, 25·20 zinc oxide, 10·41 arsenic acid, 9·01 phosphoric acid, 17·05 water. Moravicza (Banat).

414. Descloizite, $2\dot{P}b\dddot{V}_2+\dot{H}_2$.

Right prismatic. ∞P 116° 25′. H. = 3·5; G. = 5·86 to 6·1. Olive-brown to black. C.c.: 56·48 oxide of lead, 16·6 oxide of zinc, 1·16 oxide of manganese, 22·74 vanadic acid. Sierra de Cordoba in the Argentine Republic.

415. Volborthite, $4(\dot{C}u,\ \dot{C}a)\ \dddot{V}_2+\dot{H}_2$.

Hexagonal; small tabular crystals, 0P, ∞P, single or in groups. Generally massive. H. = 3; G. = 3·45 to 3·89. Olive-green; streak almost yellow. B.B. on charcoal fuses easily and forms a graphite-like slag, containing grains of copper. Sol. in n. acid, and with water gives a brick-red precipitate. C.c.: 37 to 38 vanadic acid, 39·4 to 46 copper oxide, 18·5 to 13 lime, 3·6 to 5 water. Sissersk (Urals), Nijni-Tagilsk, and Friedrichroda in Thuringia

416. Tagilite, $4\dot{C}u\dddot{P}_2+3\dot{H}_2$.

Oblique prismatic; but botryoidal and radiating-fibrous, or earthy. H. = 3; G. = 4. Emerald-green. C.c.: 61·8 copper protoxide, 27·7 phosphoric acid, and 10·5 water. Nijni-Tagilsk, and near Hirschberg.

417. Euchroite, $4\dot{C}u\dddot{A}s_2+7\dot{H}_2$.

Right prismatic. ∞P (*M*) 117° 20′, $\bar{P}\infty$ (*n*) 80° 52′, with $\infty\breve{P}2$ (*l*) and 0P (*P*) (fig. 432). Brittle. H. = 3·5 to 4; G. = 3·35 to 3·45. Translucent; vitreous. Emerald- or leek-green; streak verdigris-green. B.B. in forceps fuses to a greenish brown crystallized mass. Easily sol. in n. acid. C.c.: 47 copper protoxide, 34 arsenic acid, and 19 water. Libethen in Hungary.

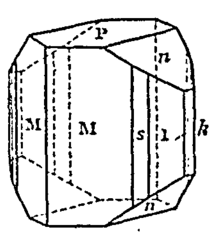


Fig. 432 (sp. 417).

418. Erinite, $5\dot{C}u\dddot{A}s_2+2\dot{H}_2$.

Reniform and foliated; conchoidal fracture. H. = 4·5 to 5; G. = 4 to 4·1. Translucent on the edges; dull resinous. Emerald- or grass-green; streak similar. C.c.: 59·9 copper protoxide, 34·7 arsenic acid, and 5·4 water. Cornwall. *Cornwallite* has 3 or 5 of water.

419. Dihyrite, $5\dot{C}u\dddot{P}_2+2\dot{H}_2$.

G. = 4·4. Oxide of copper 69, phosphoric acid 24·7, water 6·25. Rheinbreitenbach and Nijni-Tagilsk.

420. Mottramite, $5(\dot{C}u,\ \dot{P}b)\dddot{V}_2+2\dot{H}_2$.

Black crystalline crusts; streak yellow. H. = 3; G. = 5·9. C.c.: oxide of copper 20·4, oxide of lead 7·2, vanadic acid 18·7, water 3·7. Mottram in Cheshire.

421. Ehlite $5\dot{C}u\dddot{P}_2+3\dot{H}_2$.

Right prismatic; botryoidal, radiating, foliated. H. = 1·5 to 2; G. = 3·8 to 4·27. Translucent on the edges; pearly on the cleavage. Verdigris-green; streak paler. C.c.: 67 copper protoxide, 24 phosphoric acid, and 9 water. Ehl on the Rhine, Nijni-Tagilsk, Libethen.

422. Tyrolite, $5\dot{C}u\dddot{A}s_2+9\dot{H}_2$.

Right prismatic. Cl. basal, perfect; reniform. Radiate-foliaceous. H. = 1·5 to 2; G. = 3. Lustre pearly on cleavage face. Colour apple-green and verdigris-green to sky-blue; streak paler. Subtranslucent. C.c.: oxide of copper 50·3, arsenic acid 29·2, water 20·5. Tyrol, Hesse, Thuringia.

423. Phosphorochalcite (*Lunnite*), $6\dot{C}u\dddot{P}_2+3\dot{H}_2$.

Oblique prismatic. Crystals ∞P^c2 (*f*) 38° 56′, P (*P*) 117° 49′, with 0P (*a*) and $\infty P^c\infty$ (*c*) (fig. 433); usually small and indistinct; more common in spherical or reniform and radiated-fibrous masses. H. = 5; G. = 4·1 to 4·3. Translucent throughout or on the edges; adamantine to resinous. Blackish-, emerald-, or verdigris-green. C.c.: 70·8 copper protoxide, 21·2 phosphoric acid, and 8 water. Cornwall, Rheinbreitenbach, Nijni-Tagilsk.

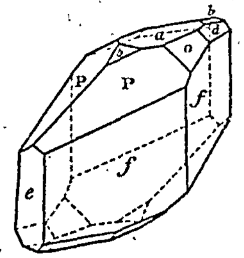


Fig. 433 (sp. 423).

424. Clinoclase, $6\dot{C}u\dddot{A}s_2+3\dot{H}_2$.

Oblique prismatic, C 80° 30′. 0P (*P*), ∞P (*m*) 56°, $\frac{4}{3}P^c\infty$ (*a*) 99° 30′, (*r*) 123° 48′ (figs. 434, 435); and hemispherical. Cl. basal, perfect. H. = 2·5 to 3; G. = 4·2 to 4·4. Translucent; vitreous; pearly on cl. Dark verdigris-green to sky-blue; streak blue. C.c.: 62·6 copper protoxide, 30·3 arsenic acid, 7·1 water. Cornwall, Tavistock, Erzgebirge.

425. Mixite.

Oblique prismatic or anorthic (?). Radiating, centrally granular. ∞P 125°. H. = 3 to 4; G. = 2·66. Emerald-green to blue-green; streak paler. C.c.: 43·21 copper oxide, 13·1 bismuth oxide, 30·45 arsenic acid, 11·1 water. Geistergang, Joachimsthal.

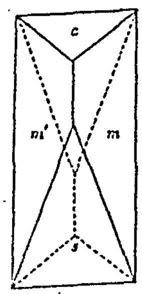


Fig. 434 (sp. 424).

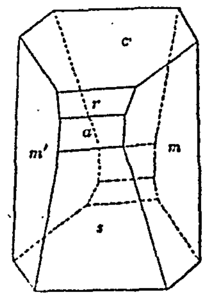


Fig. 435 (sp. 424).

426. Rhagite, $5\dot{B}i_22\dddot{A}s_2+8\dot{H}_2$.

Grape-like groups of minute crystals. Colour yellowish green; streak white. Lustre wax-like; brittle. H. = 5; G. = 6·82. C.c.: bismuth oxide 79·5, arsenic acid 15·6, water 4·9. Neustädtel near Schneeberg.

427. Trögerite, $3\dot{U}\dddot{A}s_2+12\dot{H}_2$.

Oblique prismatic, C 80°. Crystals thin tabular. Cl. clinodiagonal, perfect. Lustre pearly. G. = 3·3. Lemon-yellow. C.c.: 65·95 oxide of uranium, 17·56 arsenic acid, 16·49 water. In closed tube gives off water, and becomes golden brown, but again yellow on cooling. Neustädtel.

428. Struvite, $(N\dot{H}_4,\ 2\dot{M}g)\ \dddot{P}_2+12\dot{H}_2$.

Right prismatic. $\bar{P}\infty$ (*a*) 63° 7′, $\breve{P}\infty$ (*c*) 95°, $4\bar{P}\infty$ (*b*) 30° 32′, $\infty\breve{P}\infty$ (*n*), $\frac{1}{4}\bar{P}\infty$ (*m*) 123°, 0P (*o*) (fig. 436). Cl. brachydiagonal, perfect. H. = 1·5 to 2; G. = 1·66 to 1·75. Transparent or opaque; vitreous. Colourless, but yellow or brown. C.c.: 29·9 phosphoric acid, 16·3 magnesia, 10·6 ammonia, and 44 water. Under St Nicholas church at Hamburg, and in guano from South America.

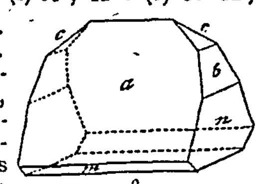


Fig. 436.

429. Arseniosiderite, $3\dot{C}a\dddot{A}s_2+3\dddot{F}e_2\dddot{A}s_2+6\dot{H}_2$.

Spherical and fibrous; friable. H. = 1·2; G. = 3·52 to 3·88. Opaque; silky. Golden yellowish brown; streak yellowish brown. C.c.: peroxide of iron 39·4, lime 13·8, arsenic acid 37·9, water 8·9. Romanèche near Macon.

430. Chalcosiderite.

Anorthic. Light green crystals. G. = 3·11. C.c.: 42·8 peroxide of iron, 8·1 oxide of copper, 4·45 alumina, 30·54 phosphoric acid, 15 water. Cornwall.

431. Lazulite, $\dddot{A}l_2\dddot{P}_2+(\dot{M}g,\ \dot{F}e)_3\dddot{P}_2+2\dot{H}_2$.

Oblique prismatic, C 88° 2′. ∞P 91° 30′, P (*e*) 99° 40′, −P (*p*) 100° 20′. Crystals often tabular through distortion; twins on 0P, and $\infty P^c\infty$; also massive; fracture splintery. Cl. ∞P. H. = 5 to 6; G. = 3 to 3·1. Translucent; vitreous. Indigo- and smalt-blue to greenish; streak white. In closed tube yields water, and loses colour. Soluble in acids after ignition. C.c.: 31·7 alumina, 10 magnesia, 6 protoxide of iron, 44 phosphoric acid, and 6 water. Salzburg, Styria, Brazil, Georgia, Lincoln in North Carolina.

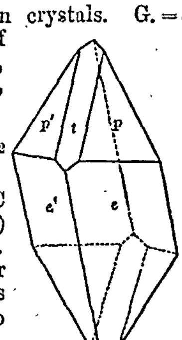


Fig. 437 (sp. 431).

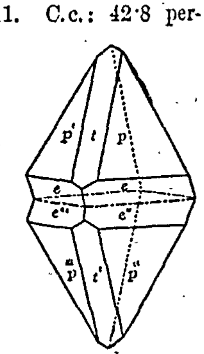


Fig. 438 (sp. 431).

432. Childrenite, $2(\dot{F}e, \dot{M}n)_4\dddot{\bar{P}} + \dddot{Al}\dddot{\bar{P}} + 15\dot{H}$. $\bar{P} = P_2, \dot{H} = H_2$, &c.

Right prismatic. Polar edges 101° 43′, 130° 10′, middle 98° 44′; usual form $\breve{P}$, $2\breve{P}\infty$, $\infty\bar{P}\infty$ (*c*, *a*, P, fig. 439). H. = 4·5 to 5; G. = 3·18 to 3·3. Translucent; vitreous. Yellowish white to wine- or ochre-yellow, brown, or almost black. C.c.: 30·7 iron protoxide, 9 manganese protoxide, 14·5 alumina, 29 phosphoric acid, and 17 water. Tavistock, Crinnis and Callington (Cornwall).

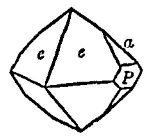


Fig. 439.

433. Eosphorite $(\dot{F}e, \dot{M}n)_2\dddot{Al}, \dddot{\bar{P}} + 4\dot{H}$.

Right prismatic. P (*p*) 133° 32′ and 118° 56′; ∞P (*i*) 104° 19′; $\infty\bar{P}\infty$ (*a*), $\infty\breve{P}\infty$ (*b*), $\infty\breve{P}2$ (*g*), $\frac{4}{3}\breve{P}\frac{4}{3}$ (*q*), $2\breve{P}2$ (*s*) (polar edges 130° 26′ and 98° 42′) (fig. 440). Cl. macrodiagonal. H. = 5; G. = 3·13. Pale red. Vitreous. C.c.: 22 alumina, 7·4 protoxide of iron, 23·5 oxide of manganese, 31·5 phosphoric acid, 15·6 water. Fairfield (Connecticut).

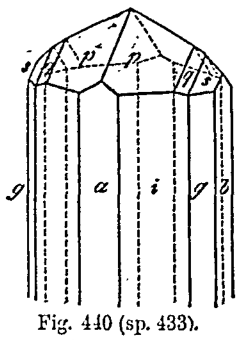


Fig. 440 (sp. 433).

434. Liroconite, $\dot{C}u_8\dddot{\bar{A}}s + \dddot{Al}\dddot{\bar{A}}s + 24\dot{H}$.

Oblique prismatic, C 88° 33′. ∞P (*d*) 61° 31′, $P^c\infty$ (*o*) 74° 21′ (fig. 349). H. = 2 to 2·5; G. = 2·8 to 3. Translucent; vitreous or resinous. Azure-blue to verdigris-green; streak paler. C.c.: 36·6 protoxide of copper, 11·9 alumina, 26·6 arsenic acid, 24·9 water. Redruth, Herrengrund in Hungary.

435. Chalcophyllite, $\dot{C}u_6\dddot{\bar{A}}s + 12\dot{H}$.

Hexagonal rhombohedral; R 69° 48′ (fig. 441). Cl. basal, perfect; sectile. H. = 2; G. = 2·4 to 2·6. Transparent; vitreous to adamantine. Pearly on 0R (*o*). Emerald- to grass- and verdigris-green; streak pale green. Soluble in acids and ammonia. C.c.: protoxide of copper 49·6, arsenic acid 18, water 32·4. Redruth in Cornwall, Saida in Saxony, Moldawa in the Banat.

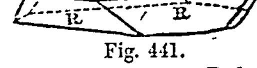


Fig. 441.

436. Uranite, $(\dot{C}a, \dddot{\bar{U}}_2)\dddot{\bar{P}} + 8\dot{H}$.

Right prismatic. ∞P 90° 43′; P middle edge 127° 32′. 0P : P 116·14; 0P : $2\bar{P}\infty$ 109° 6′; 0P : $2\breve{P}\infty$ 109° 19′ (figs. 442, 443). Crystals flat. Cl. basal, perfect; sectile. H. = 1 to 2; G. = 3 to 3·2. Translucent; pearly on 0P. Sulphur-yellow to siskin-green; streak yellow. C.c.: 15·5 phosphoric acid, 62·6 uranium peroxide, 6·1 lime, and 15·3 water. Cornwall, Autun and Limoges in France, Johann-Georgenstadt and Eibenstock in Saxony, Chesterfield in Massachusetts.

Fig. 442.

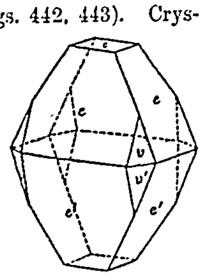


Fig. 443.

437. Uranospinite, $(\dot{C}a, \dddot{\bar{U}}_2)\dddot{\bar{A}}s + 8\dot{H}$.

Right prismatic; quadrangular, scale-like crystals. Cl. basal, perfect. H. = 2·3; G. = 3·45. Siskin-green. C.c.: lime 5·47, sesquioxide of uranium 59·18, arsenic acid 19·37, water 16·29. Neustädtel.

438. Uranocircite, $(\dot{B}a, \dddot{\bar{U}}_2)\dddot{\bar{P}} + 8\dot{H}$.

Yellowish green crystals, isomorphous with 437. Cl. basal. G. = 3·53. C.c.: sesquioxide of uranium 56·86, baryta 14·57, phosphoric acid 15·1, water 14. Falkenstein in Voigtland.

439. Chalcolite, $(\dot{C}u, \dddot{\bar{U}}_2)\dddot{\bar{P}} + 8\dot{H}$.

Pyramidal. P middle edge 142° 8′; P∞ 128° 14′. Crystals 0P, P, ∞P∞, P∞. Cl. basal, perfect; pearly lustre; brittle. H. = 2 to 2·5; G. = 3·5 to 3·6. Grass- to emerald- or verdigris-green; streak apple-green. C.c.: 15·2 phosphoric acid, 61 uranium peroxide, 8·5 copper protoxide, and 15·3 water. Redruth and St Austell, Johann-Georgenstadt, Eibenstock, Schneeberg Bodenmais, Baltimore.

440. Zeunerite, $(\dot{C}u, \dddot{\bar{U}}_2)\dddot{\bar{A}}s + 8\dot{H}$.

Pyramidal. P middle edge 142° 6′. 0P : P 109° 57′. Crystals tabular. Cl. basal. H. = 2·5; G. = 3·53. Grass-green. Lustre pearly. C.c.: 7·7 oxide of copper, 55·95 sesquioxide of uranium, 14 water. Huel Gorland in Cornwall, Neustädtel, Joachimsthal, Zinnwald, Wittichen.

441. Walpurgite, $5\dddot{\bar{B}}i\dddot{\bar{A}}s + 3\dddot{\bar{U}}\dddot{\bar{A}}s + 10\dot{H}$.

Anorthic; in scaly crystals. Wax-yellow to pomegranate-red. Adamantine to greasy. H. = 3·5; G. = 5·76. C.c.: sesquioxide of bismuth 60·4, sesquioxide of uranium 20·4, arsenic acid 13, water 4·5. Neustädtel.

442. Plombgomme, $\dot{P}b_3\dddot{\bar{P}} + 6\dddot{Al}\dot{H}_3$.

Reniform or stalactitic; fracture conchoidal and splintery. H. = 4 to 4·5; G. = 6·3 to 6·4. Translucent; resinous. Yellowish or greenish white to reddish brown. C.c.: 38 protoxide of lead, 35 alumina, 8 phosphoric acid, and 19 water; but with 2 chloride of lead. Poullauouen, Nuissière (near Beaujeu), Georgia.

Compounds of Phosphates, Vanadiates, and Arseniates with Haloid Salts.

443. Apatite, $3\dot{C}a\dddot{\bar{P}} + Ca(Cl, F)$.

Hexagonal and pyramidal-hemihedric. P 80° 26′. The most common forms are ∞P (M); ∞P2 (*n*); 0P (*m*); P (*x*); the base 0P seldom wanting (figs. 92, 95, 96, 97, 98). The crystals are short-prismatic or thick-tabular; also granular, fibrous, or compact; fracture conchoidal or splintery; brittle. H. = 5; G. = 3·1 to 3·25. Transparent to opaque; vitreous to resinous. Colourless and white, but generally light green, grey, blue, violet, or red. C.c.: phosphate of lime (89 to 92·3), with chloride (to 11) or fluoride (to 7·7) of calcium, or both. Disseminated in granite, gneiss, mica and hornblende slates, primary limestones, and trap rocks; also in beds and veins. Sutherland, Ross, and Aberdeen, in granite and limestone; Cumberland, Devonshire, and Cornwall; in tin-mines in Saxony; Bohemia, St Gotthard, Tyrol; Kragerö in Norway, New York, Canada.

444. Pyromorphite, $3\dot{P}b_3\dddot{\bar{P}} + PbCl$.

Hexagonal; P 80° 44′. Crystals ∞P, 0P, with ∞P2, or P (*M*, *P*, *x*, fig. 444), occasionally thicker in the middle, or spindle-shaped; also reniform or botryoidal; fracture conchoidal or uneven. H. = 3·5 to 4; G. = 6·9 to 7. Translucent; resinous or vitreous. Colourless, but generally grass-, pistachio-, olive-, or siskin-green, and clove- or hair-brown, and scarlet (Leadhills). C.c.: 89·7 phosphate and 10·3 chloride of lead, but with 0 to 9 arseniate of lead, 0 to 11 phosphate of lime, and 0 to 1 fluoride of calcium. Elgin, Wanlockhead, also Cornwall, Derbyshire, Yorkshire, Durham, Cumberland, Wicklow; Przibram, Mies, and Bleistadt in Bohemia; Berezoff, Phœnixville in Pennsylvania, and Mexico.

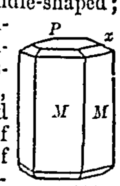


Fig. 444.

445. Vanadinite, $3\dot{P}b_3\dddot{\bar{V}} + PbCl$.

Hexagonal; P 78° 46′. Forms ∞P, 0P (*o*), P (*z*), 2P, $\frac{1}{2}$P ($b\frac{1}{2}$), ∞P2, ∞P$\frac{3}{2}$, 2P2 (fig. 445). Transparent to opaque; resinous. Honey-yellow to greyish brown; streak white. H. = 3; G. = 6·8 to 7·2. C.c.: oxide of lead 70·83, vanadic acid 19·35, lead 7·2, chlorine 2·62. Wanlockhead, Windischkappel in Carinthia, Haldenwirthshaus in the Black Forest, Bolet in West-Gotland, Berezovsk, Zimapan in Mexico, Cordoba in the Argentine Republic.

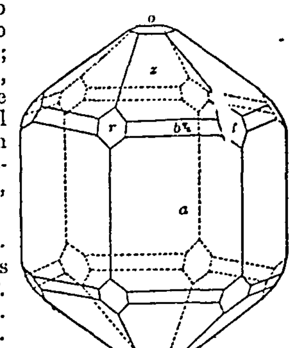


Fig. 445 (sp. 445).

446. Mimetesite, $3\dot{P}b_3\dddot{\bar{A}}s + PbCl$.

Hexagonal; P 81° 48′. Crystals ∞P, 0P, P (figs. 91, 444), or P, 0P. Cl. P; fracture conchoidal or uneven. H. = 3·5 to 4; G. = 7·19 to 7·25. Translucent. Colourless, but usually honey- or wax-yellow, yellowish green or grey. C.c.: 90·7 arseniate and 9·3 chloride of lead; but part of the arsenic occasionally replaced by phosphoric acid. Leadhills, Huel Alfred and Huel Unity in Cornwall, Roughten Gill and Dry Gill in Cumberland, Beeralston in Devonshire, Johann-Georgenstadt, Zinnwald, Badenweiler, St Prix in France, Nertchinsk, and Zacatecas in Mexico.

447. Wagnerite, $\dot{M}g_3\dddot{\bar{P}} + MgF$.

Oblique prismatic, C 63° 25′. ∞P 57° 35′. Cl. prismatic, and orthodiagonal imperfect; fracture conchoidal or splintery. H. = 5 to 5·5; G. = 3 to 3·2. Translucent or transparent; resinous. Wine-yellow and white. C.c.: 43·3 phosphoric acid, 11·4 fluorine, 37·6 magnesia, and 7·7 magnesium; but with 3 to 4·5 iron protoxide and 1 to 4 lime. Werfen in Salzburg.

448. Triplite, $(\dot{F}e, \dot{M}n)_3\dddot{\bar{P}} + RF$.

Oblique prismatic; only granular. Cl. in two directions at right angles; fracture conchoidal. H. = 5 to 5·5; G. = 3·6 to 3·8. Translucent or opaque; resinous. Chestnut- or blackish-brown; streak yellowish grey. C.c.: iron and manganese protoxides, with 33 phosphoric acid, and 7 or 8 fluorine. Limoges, Schlaggenwald.

449. Zwieselite, $(\dot{F}e, \dot{M}n)_3\dddot{\ddot{P}} + FeF$.

Right prismatic; but only massive. Cl. basal, perfect. H. = 4·5 to 5; G. = 3·95 to 4. Brown; streak yellow. C.c.: like triplite. Zwiesel in Bavaria.

450. Amblygonite, $\dddot{A}l_5\dddot{\ddot{P}}_3 + (\dot{L}i, \dot{N}a)_5\dddot{\ddot{P}}_3 + AlF_3 + (Li, Na)F$.

Anorthic; crystals rare; coarse granular. Cl. 0P, pearly, meeting two others at 105° and 87° 40′. Fracture uneven and splintery. H. = 6; G. = 3 to 3·1. Translucent; vitreous. Greyish or greenish white to pale mountain-green. C.c.: 47·9 phosphoric acid, 34·5 alumina, 6·9 lithia, 6 soda, and 8·3 fluorine. Penig, Arendal, Montebras (Creuse, France), also Hebron and Paris in Maine. *Montebrasite* has no soda.

451. Durangite, $(\dddot{R}_2)\,\dddot{\ddot{A}}s + 2NaF$.

Oblique prismatic; crystals like keilhauite (sp. 669). ∞P 110° 10′; P 112° 10′. Cl. prismatic. H. = 5; G. = 3·95 to 4. Bright orange-red; streak cream-yellow. Vitreous. C.c.: alumina 17·2, iron protoxide 9·2, arsenic acid 53, soda 13·1, fluorine 7·7. Durango (Mexico).

452. Herderite.

Right prismatic. P polar edges 77° 20′ and 141° 16′; ∞P̆ 115° 53′. Fracture conchoidal. H. = 5; G. = 2·9 to 3. Translucent; vitreous, inclining to resinous. Yellowish or greenish white. Ehrenfriedersdorf in Saxony. An anhydrous phosphate of alumina with lime and fluorine.

Phosphates with Sulphates and Borates.

453. Svanbergite.

Rhombohedral; R 90° 35′. H. = 4·5; G. = 2·57. Vitreous to adamantine. Honey-yellow, reddish brown, and rose-red; streak reddish. Subtransparent. C.c.: 37·8 alumina, 6 lime, 17·3 sulphuric acid, 12·8 soda, 17·8 phosphoric acid, 6·8 water. Horrsjöberg in Wermland.

454. Diadochite, $\dddot{F}e_3\dddot{\ddot{P}}_2 + 2\dddot{F}e\dddot{S}_2 + 32\dot{H}$.

Reniform and stalactitic; fracture conchoidal. H. = 3; G. = 1·9 to 2. Resinous; vitreous. Yellow or yellowish brown; streak white. C.c.: 36·7 iron protoxide, 14·8 phosphoric acid, 15·2 sulphuric acid, and 30·3 water. Gräfenthal and Saalfeld.

455. Pitticite, $\dddot{F}e_2\dddot{S}_3 + 2\dddot{F}e\dddot{\ddot{A}}s + 24\dot{H}$.

Reniform and stalactitic; brittle; fracture conchoidal. H. = 2·3; G. = 2·3 to 2·5. Translucent throughout, or on the edges; resinous to vitreous. Yellowish, reddish, or blackish brown, sometimes in spots or stripes; streak light yellow or white. C.c.: 35 iron peroxide, 26 arsenic acid, 14 sulphuric acid, and 24 water. In many old mines, as Freiberg and Schneeberg.

456. Beudantite.

Rhombohedral; R 91° 18′. H. = 3·5; G. = 4. Vitreous. Olive-green; streak greenish yellow. C.c.: oxide of iron 40·69, oxide of lead 24·05, sulphuric acid 13·76, phosphoric acid 8·97, water 9·77. Dernbach in Nassau, Cork in Ireland.

457. Lüneburgite $(2\dot{M}g, \dot{H})\,\dddot{\ddot{P}} + \dot{M}g\dddot{B} + 7\dot{H}$.

Concretions of fibrous structure. C.c.: 25·2 magnesia, 29·83 phosphoric acid, 14·74 boracic acid, 30·23 water. Lüneburg.

ARSENITES.

458. Ecdemite, $\dot{P}b_3\dddot{A}s_2 + 2PbCl_2$.

Pyramidal. Cl. 0P. H. = 2·5 to 3; G. = 7·14. Pale green. Vitreous on cleavage; resinous on fracture. C.c.: oxide of lead 59·67, lead 22·2, arsenious acid 10·59, chlorine 7·58. Långban in Wermland.

459. Trippkeite, $\dot{C}u\dddot{A}s$.

Pyramidal; P 111° 56′. Blue-green. Lustrous. Copiapo in Chili.

SILICATES.

Andalusite Group.

460. Andalusite, $\dddot{A}l\ddot{S}i$.

Right prismatic. ∞P (*m*) 90° 50′, P̄∞ (*r*) 109° 4′, P̆∞ (*s*) 109° 51′.

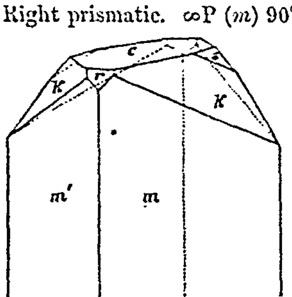


Fig. 446.

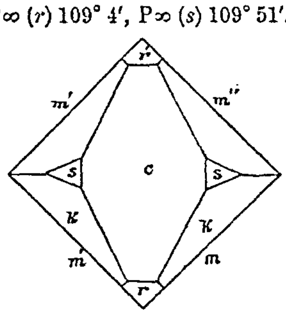


Fig. 447.

Also columnar. Cl. *m*; fracture splintery. H. = 7 to 7·5; G. = 3·1 to 3·2. Pellucid; vitreous. Grey, green, red, or blue. B.B. infusible. Not affected by acids. C.c.: alumina 63·1, silica 36·9. Clashnaree (figs. 446 to 449) and Clova in Aberdeenshire, Marnoch and Botriphnie in Banffshire, Killiney Bay in Wicklow, Andalusia, Tyrol, Penig, Massachusetts, Litchfield in Connecticut.

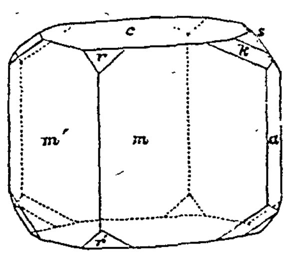


Fig. 448.

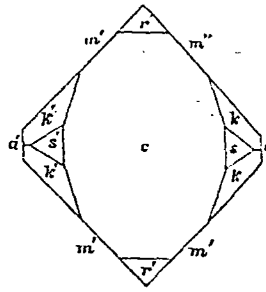


Fig. 449.

Chiastolite. H. = 5 to 5·5; G. = 3. Pale grey, yellow, green, and red. A compound structure, formed of four double wedge-shaped crystals, arranged in contact with the angles of a square conoidal crystal placed in their centre, and imbedded in a paste of clay slate. The section of the compound structure forms a tesselated cross, the appearance of which varies with the portion of the crystal which is cut. Portsoy (fig. 450) and Boharm in Banffshire, Wicklow, Keswick and Skiddaw, Brittany, Pyrenees, Maine, New Hampshire, Nova Scotia, Canada.

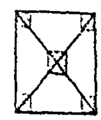


Fig. 450.

461. Cyanite (*Disthene*), $\dddot{A}l\ddot{S}i$.

Anorthic; generally broad-prismatic lengthened crystals, formed by two faces (*m*, *t*). *m* : *t* 106° 15′; *m* : *i* 145° 41′; *p* : *m* 93° 15′ (fig. 451). Hemitropes common, united by *m*. Also radiated. Cl. *m*, perfect; brittle. H. = 7, on cl. planes 5; G. = 3·5 to 3·7. Pellucid; vitreous. Cl. pearly. Colourless, and red, yellow, green, grey, and blue. B.B. infusible. Not affected by acids. C.c. same as andalusite. Hillswick in Shetland, Mount Battock, Tarfside (fig. 451), Botriphnie (Banffshire), Tyrol, St Gotthard, Bohemia, Pontivy in France.

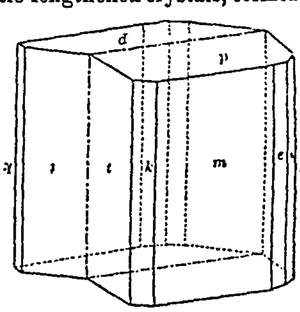


Fig. 451.

462. Sillimanite, $\dddot{A}l\ddot{S}i$.

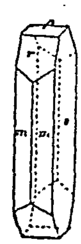
Right prismatic; ∞P 111°. Crystals fibrous, columnar, and radiating. Cl. macrodiagonal. H. = 7; G. = 3·2 to 3·26. Translucent; resinous; on cl. vitreous. Greyish, greenish, clove, or hair-brown. C.c. and chemical characters like cyanite. Tvedestrand, Norway; Chester and Norwich, Connecticut. Al_2O_3,SiO_2 is thus trimorphous. *Monrolite*, *Xenolite*, *Bucholzite*, *Fibrolite*, and *Bamlite* are varieties.

463. Topaz, $5\dddot{A}l\ddot{S}i + AlF_3 + SiF_2$.

Right prismatic. ∞P (*M*) 124° 17′, 2P̆∞ (*n*) 92° 42′, ∞P̆2 (*l*) 93° 14′, P (*o*). Crystals always prismatic (fig. 122), often hemimorphic. Cl. basal, perfect; fracture conchoidal. H. = 8; G. = 3·4 to 3·6. Transparent; vitreous. Colourless, honey-yellow, amber, pink, asparagus-green, blue. Becomes electric by heat or friction, and the yellow colours become pink. B.B. infusible. Not affected by h. acid; by digestion in s. acid gives traces of fluorine. The formula requires 33·2 silica, 56·7 alumina, 17·5 fluorine. Part of the oxygen must be replaced by fluorine, as the total of the above is 107·4. Ben-a-bourd and Arran, Scotland; Mourne Mountains, Ireland; St Michael's Mount, Cornwall; Siberia, Saxony, Bohemia, Connecticut, Australia, Ceylon, Brazil, Peru. The finest topazes are the blue from Scotland and Siberia, the pink, the yellow from Brazil, and the colourless from Peru. The last-named when cut may be distinguished at once from diamond by their electricity. *Pyrophysalite* is a massive opaque cleavable variety from Falun. *Pycnite* is a columnar straw-yellow to reddish white variety from Zinnwald in Saxony and Durango in Mexico.

464. Staurolite, $(\dddot{A}l, \dddot{F}e)\,\ddot{S}i + (\dot{F}e, \dot{M}g)\,\ddot{S}i$.

Right prismatic. ∞P (*m*) 128° 42′, P̆∞ (*r*) 70° 46′, ∞P̆∞ (*o*), 0P̆ (*p*) (fig. 452). Twins common, as figs. 140, 144, 187, 453. Cl. brachydiagonal, perfect; fracture conchoidal to splintery. H. = 7; G. = 3·5 to 3·8. Transparent to opaque; vitreous to resinous. Reddish brown; streak white. B.B. infusible. Not affected by h. acid, partially by s. acid.



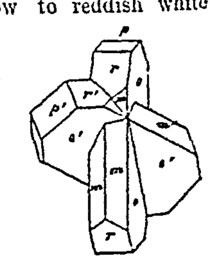


Fig. 452. (Sp. 464.) Fig. 453.

C.c.: silica 30, alumina 48·5, with 5·5 iron peroxide, 12·5 iron protoxide, 3·5 magnesia; often impure. Bixeter Voe and Unst in Shetland, Boharm and Marnoch in Banffshire, St Gotthard, Greiner in Tyrol, Finistère, Urals, and North America. *Xantholite* is a yellow variety from Urquhart (Inverness).

465. Sapphirite, $4\dot{M}g$, $5\dddot{A}l$, $2\dddot{S}i$.

Oblique prismatic; granular. H. = 7 to 8; G. = 3·4 to 3·5. Vitreous; pale blue or green; translucent; dichroic. C.c.: alumina 63·2, magnesia 19·3, silica 14·9. Fiskenaes in Greenland.

Tourmaline Group.

466. Tourmaline, $\dot{R}_3\dddot{S}i + \dddot{R}\dddot{S}i$.

Rhombohedral; R 133 10′. Crystals of 0R (k'), $-\frac{1}{2}$R; usually long prismatic, and striated (fig. 45, and 249 to 252). Generally hemimorphic; also radiating and fibrous; fracture conchoidal to uneven. H. = 6·5 to 7·5; G. = 3 to 3·3. Black varieties opaque, others transparent; vitreous. Generally black; but colourless, yellow, brown, blue, green, and rose-red; streak white. Different colours often disposed in layers parallel to the axis; and portions of one crystal differing also in colour along the axis. By friction acquires positive electricity; and becomes electrically polar when heated. Powder insol. in h. acid; imperfectly in s. acid. C.c. complex, but all with water and fluorine, some with boracic acid. Coarse black columnar varieties, called *Schorl*, very common in granite and gneiss. Black occur at Portsoy in Banff, Clova, Cabrach, and Rubislaw in Aberdeenshire, Bovey in Devonshire, St Just in Cornwall, in Greenland, Arendal, Tyrol, and North America; blue or *Indicolite* at Utö in Sweden; green at Glen Skiag in Cromarty. Crystals ruby-red within, surrounded by green or red at one extremity and green at the other, also blue and pink, at Albany, Paris, and Hebron in Maine. Currant-red or *Rubellite* in India and Ceylon, also in Siberia and Brazil.

467. Datholite, $\dot{C}a\dddot{B} + \dot{C}a\dddot{S}i_2 + \dot{H}$.

Oblique prismatic, C 89° 51′. ∞P (g) 115° 22′, ∞P°2 (f) 76° 38′. P (P) 120°, −P°∞ (a) 45° 8′, ∞P°∞ (s), 2P°∞ (o) (fig. 454); or rhombic with $b:f$ 90°, $b:a$ 135°, $b:c$ 141° 9′, and $f:g$ 160° 39′. Fracture uneven, or conchoidal. H. = 5 to 5·5; G. = 2·9 to 3. Transparent or translucent; vitreous. Colourless and tinted greenish, yellowish, or pink. In closed tube yields water. B.B. intumesces and melts easily to a clear glass, colouring the flame green; the powder gelatinizes in h. acid. C.c.: 38·1 silica, 21·6 boracic acid, 34·7 lime, and 5·6 water. Bishopton in Renfrew, Glen Farg in Perthshire (fig. 455), Salisbury Crags and Corstorphine Hill near Edinburgh, Arendal, Utö, Andreasberg, Seisser Alp, Connecticut, and New Jersey. Figs. 238, 239 are pseudomorphs of quartz after datholite termed *Haytorite*.

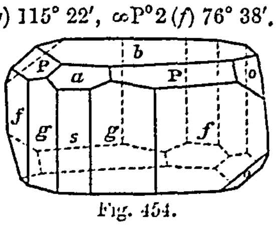


Fig. 454.

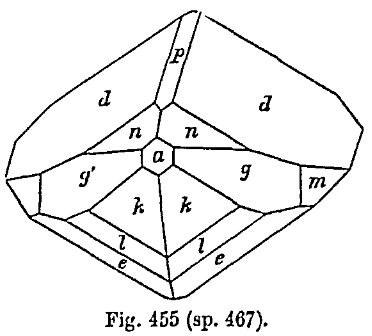


Fig. 455 (sp. 467).

468. Euclase, $2\dddot{G}l\dddot{S}i + \dddot{A}l\dot{H}$.

Oblique prismatic, C 79° 44′. ∞P°2 (s) 115°; 3P°3 (f) 105° 49′. Crystals specially of ∞P°2, ∞P°∞ (T), 3P°3. Cl. clinodiagonal, perfect; very brittle and fragile; fracture conchoidal.

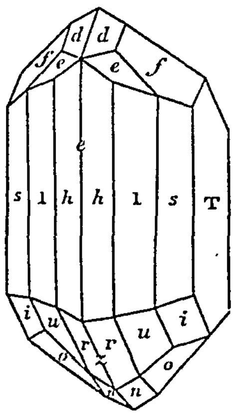


Fig. 456.

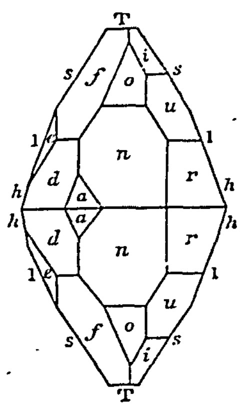


Fig. 457.

H. = 7·5; G. = 3 to 3·1. Transparent; splendent; vitreous. Mountain-green, passing into blue, yellow, or colourless. B.B. intumesces, becomes white, and melts in thin splinters to a white enamel. Not affected by acids. C.c.: 42 silica, 35 alumina, 18 glucina, 6 water. Peru and Brazil, and Southern Urals. Cannot be used as a gem on account of its brittleness; whence its name.

469. Homilite.

Oblique prismatic, C 89° 21′. H. = 5·5; G. = 3·28. Black and brownish black. Vitreous. C.c.: 27·28 lime, 16·25 protoxide of iron, 31·87 silica, 18·1 boracic acid. Stokö and Brevig (Norway).

470. Botryolite.

Fine fibrous, botryoidal, or reniform. Snow-white to hair-brown. Chemical and physical characters like datholite, but 10·64 of water,—being 2 equivalents. Arendal.

471. Gadolinite, $(\dot{Y}, \dot{C}e, \dot{F}e)_2\dddot{S}i$.

Oblique prismatic, C 89° 28′. ∞P 116°; P 120° 56′ (fig. 458). Fracture conchoidal, or splintery. H. = 6·5 to 7; G. = 4 to 4·4. Translucent on the edges; vitreous to resinous. Black; streak greenish grey. B.B. the conchoidal (vitreous) varieties incandesce; gelatinizes in h. acid. C.c.: 36 to 51 yttria, 10 to 15 iron protoxide, 5 to 17 protoxide of cerium with lanthanum, 0 to 12 glucina, and 25 to 29 silica. Hitterö in Norway, Ytterby, Broddbo and Finbo near Falun.

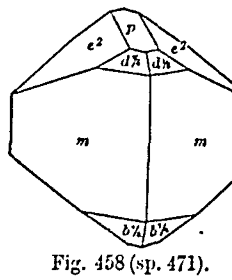


Fig. 458 (sp. 471).

Epidote Group.

472. Zoisite, $4\dot{C}a$, $3\dddot{A}l$, $6\dddot{S}i + \dot{H}$.

Right prismatic. ∞P 116° 26′; ∞P̆2 145° 24′; ∞P̄3 156° 40′; P̄∞ 122° 4′; 2P̆∞ 111 6′ (fig. 459). Cl. brachydiagonal, perfect. H. = 6; G. = 3·2 to 3·4. White, brownish grey, and dark green. B.B. intumesces, and forms a white or yellow porous mass; and on the edges fuses to a clear glass. C.c.: 29·8 alumina, 24·35 lime, 2·8 oxide of iron, 40·3 silica, and 2·1 water. Glen Urquhart, Dalnain, and Allt Gonolan, Inverness; Sterzing in Tyrol, the Sau Alp in Carinthia, the Urals, and Connecticut. *Thulite*, peachblossom-red, from Souland in Thelemark (Norway), is similar.

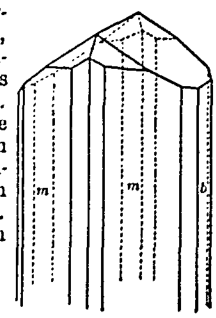


Fig. 459 (sp. 472).

473. Epidote, $4\dot{C}a$, $3\dddot{A}l$, $6\dddot{S}i + \dot{H}$.

Oblique prismatic, C 89° 27′. ∞P°∞ (M), ∞P 2 (o) 63° 1′, P°∞ (T) 64° 36′, −P (n) 70° 25′, −P̄∞ (r) 63° 42′, P (z) 70°. Crystals complex, with many partial forms. Hemitropes united by T; also columnar and granular. Cl. M, perfect; also T, forming 115° 24′; fracture conchoidal to splintery. H. = 6 to 7; G. = 3·2 to 3·5. Pellucid; vitreous. Green to yellowish grey. B.B. fuses and swells to a dark brown slag; after fusion soluble with gelatinization in h. acid. C.c.: 27·4 alumina, 8·5 iron peroxide, 23·9 lime, 38·3 silica, 1·9 water. Shetland, Glenelg in Inverness, Tilquilly in Aberdeen, in gneiss; in amygdaloid in Mull and Skye; in granite at Cassencary in Kirkcudbright; Arendal, Dauphiné, Greenland, the Urals, North America. *Withamite* from Glencoe is a red, strongly dichroic variety. *Piedmontite* or *Manganese Epidote*, brownish violet, from St Marcel, has 20 per cent. of manganese peroxide.

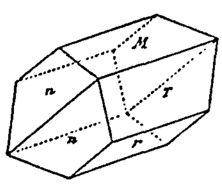


Fig. 460.

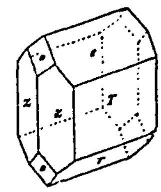


Fig. 461.

474. Allanite (*Orthite, Cerine*), $\dot{R}_3\dddot{S}i_2 + \dddot{R}\dddot{S}i$.

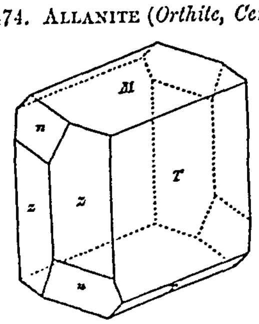


Fig. 462.

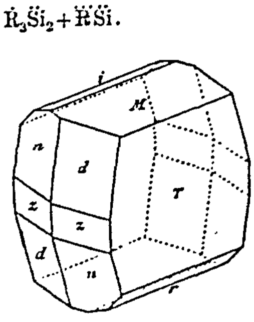


Fig. 463.

Oblique prismatic, C 65°. ∞P (z) 70° 48′, P (n) 71° 27′, −P (d)

96° 40′, 0P (*M*), $\bar{P}\infty$ (*r*), $\infty P\infty$ (*T*). *M* : *T* 115°, *T* : *n* 111° 21′, *T* : *d* 130° 18′. Often massive or granular; fracture conchoidal. H. = 6; G. = 3·4 to 3·8. Translucent on edges; vitreous to resinous. Black to brown or greenish; streak brownish grey. B.B. froths and melts to a brown glass. Gelatinous with h. acid. C.c.: 12 to 18 alumina with peroxide of iron, 13 to 26 oxide of cerium and lanthanum, 2 to 12 yttria, 4 to 20 protoxide of iron, 30 of silica. Small crystals common in the syenitic granites of Scotland; as at Lairg, Boat of Garten (fig. 463), Aboyne, and Criffel. In limestone at Urquhart (fig. 462), Greenland, Hitterö and Snarum, Thuringia, Pennsylvania, New Jersey. *Orthite* (massive) at Finbo, Kragerö, and Falun. *Cerine* (granular) at Riddarhyttan. *Pyrorthite* has carbonaceous matter. *Bodenite* is a variety.

475. IDOCRASE, $3(\dot{Ca}, \dot{Mg})_3\dddot{Si} + 2\overline{Al}\dddot{Si}$.

Pyramidal; P (*c*) 74° 27′ (figs. 464 to 466). Crystals ∞P (*d*),

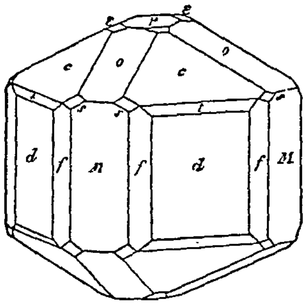


Fig. 464.

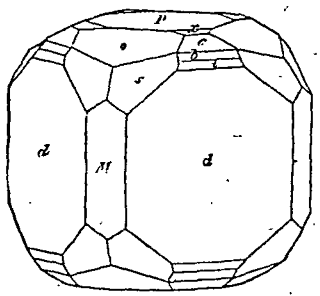


Fig. 465.

$\infty P\infty$ (*M*), P (*c*), 0P (*p*), $P\infty$ (*o*) 56° 29′, $\infty P2$ (*f*). Prismatic, striated; also granular; fracture uneven. H. = 6·5; G. = 3·35 to 4. Pellucid; vitreous to resinous. Brown, green, yellow; streak white. B.B. fuses easily, with intumescence, to a green or brown glass. Partially sol. in h. acid; after ignition totally, gelatinizing. C.c.: alumina 16, peroxide of iron 7, lime 34, silica 38. Glen Gairn and Crathie, Aberdeenshire, in limestone; Broadford, Skye; Wicklow and Donegal, Ireland; Egg, Norway; Mussa, Piedmont; Vesuvius; Wilui river, near Lake Baikal (fig. 463). *Cyprine* from Thelemark is azure-blue, from copper.

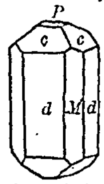


Fig. 466.

OLIVINE GROUP.

476. FORSTERITE, $\dot{Mg}_2\dddot{Si}$.

Right prismatic. Like olivine (sp. 478). H. = 6 to 7; G. = 3·2 to 3·3. Vitreous; transparent. White, wax-yellow, greenish; streak white. C.c.: magnesia 57·1, silica 42·86. Vesuvius. *Boltonite*, red, is from Massachusetts.

477. FAYALITE, $\dot{Fe}_2\dddot{Si}$.

Right prismatic; *n* : *n′* 49° 36′ (fig. 467). Massive. Cl. rectangular. Black, greenish, or brownish. Metallic to resinous; fracture conchoidal; magnetic. H. = 6·5; G. = 4 to 4·1. C.c.: protoxide of iron 70·5, silica 29·5. Mourne Mountains, Ireland; Fayal, Azores.

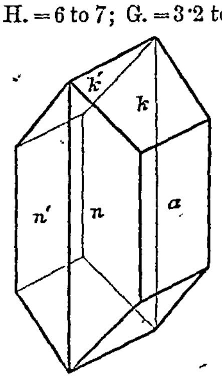


Fig. 467 (sp. 477).

478. CHRYSOLITE (*Olivine*, *Peridote*), $(\dot{Fe}, \dot{Mg})_2\dddot{Si}$.

Right prismatic. P (*e*) 85° 16′ and 139° 54′; middle 108° 30′. ∞P (*n*) 130° 2′, $\bar{P}\infty$ (*d*) 76° 54′, $2\breve{P}\infty$ (*k*) 80° 53′, $\infty\bar{P}\infty$ (*M*) (fig. 468). Also massive. Cl. brachydiagonal, perfect; fracture conchoidal. H. = 6·5 to 7; G. = 3·3 to 3·5. Transparent; vitreous. Olive-green, yellow, brown, and colourless. B.B. infusible. Soluble, with gelatinizing, in acids. C.c.: 47 magnesia, 12 protoxide of iron, 40 silica. Talisker in Skye, Haalival in Rum, Elie in Fife, Unkel on the Rhine, Vesuvius, Esneh in Egypt, Brazil. *Hyalosiderite*, brown and yellow, with metallic lustre and 30 per cent. protoxide of iron, is from the Kaiserstuhl in the Breisgau.

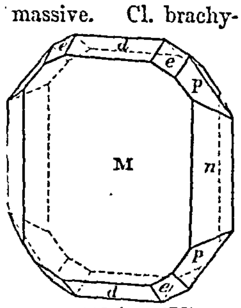


Fig. 468 (sp. 478).

479. TEPHROITE, $\dot{Mn}_2\dddot{Si}$.

Right prismatic; granular, with rectangular cleavages. Ash-grey, rose-red. Adamantine; translucent. H. = 5·5 to 6; G. = 4 to 4·1. C.c.: protoxide of manganese 70·2, silica 29·8. Franklin and Sparta in New Jersey.

480. KNEBELLITE, $\dot{Fe}_2\dddot{Si} + \dot{Mn}_2\dddot{Si}$.

Massive. Grey, brown, green, black. Glistening; brittle. H. = 6·5; G. = 3·71. C.c.: protoxide of iron 35·5, protoxide of manganese 35, silica 29·5. Ilmenau, Dannemora in Sweden.

481. MONTICELLITE, $\dot{Ca}_2\dddot{Si} + \dot{Mg}_2\dddot{Si}$.

Right prismatic. P (*f*) 110° 43′ and 97° 55′, ∞P (*s*) 98° 7′, $\infty\breve{P}2$ (*n*) 133° 6′, $\breve{P}\infty$ (*k*) 81° 57′, $\frac{1}{2}\breve{P}\infty$ (*h*) 120° 8′, $\breve{P}2$ (*c*) 141° 47′ and 82°, $\infty\breve{P}\infty$ (*b*) (fig. 469). Vitreous. Grey, yellowish and greenish, and white; streak white. Translucent. H. = 5 to 5·5; G. = 3 to 3·25. C.c.: lime 35, magnesia 21·9, protoxide of iron 5·6, silica 37·5. Sol. in h. acid, gelatinizing. Somma (Milan).

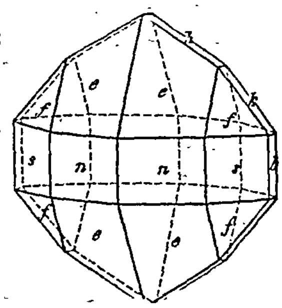


Fig. 469 (sp. 481).

482. CHONDRODITE (*Humite*), $\dot{Mg}_5\dddot{Si}_2$.

Right prismatic. P middle edge 156° 38′, polar edges 131° 34′ and 54° 28′ (figs. 470 to 472). Crystals monoclinic in habit, often granular-massive. H. = 6·5; G. = 3·15 to 3·25. Translucent; vitreous to resinous. Yellow, red, brown, green, and black; streak white. B.B. infusible. Decomposed by acids. C.c.:

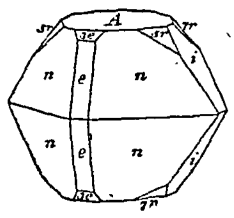


Fig. 470.

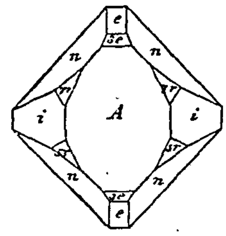


Fig. 471.

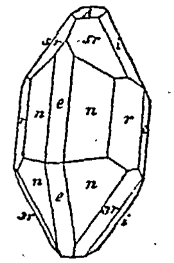


Fig. 472.

silicate of magnesia, with 2 to 3 of fluorine. From limestone on Loch Ness (?); Pargas, Finland; Gallsjö and Aker, Sweden; New York; Sparta, New Jersey. *Humite*, from Somma.

483. LIEVRITE, $3(\dot{Fe}, \dot{Ca})_2\dddot{Si} + \overline{Fe}\dddot{Si} + \dot{H}$.

Right prismatic. P (*o*) polar edges 139° 30′ and 117° 27′; ∞P 112° 38′, $\bar{P}\infty$ (*d*) 112° 49′, $\infty P2$ (*s*) 106° 15′. Crystals (fig. 124) are long-prismatic and vertically striated; also radiated, columnar, or fibrous; brittle. H. = 5·5 to 6; G. = 3·9 to 4·2. Opaque; resinous or imperfect metallic. Brownish or greenish black; streak black. B.B. fuses easily to a black magnetic globule. Sol. in h. acid, forming a yellow jelly. C.c.: 29·3 silica, 19·6 iron peroxide, 35·2 iron protoxide, 13·7 lime, and 2·2 water. Rio in Elba, Fossum, Kupferberg, Rhode Island, and Greenland.

484. CERITE $(\dot{Ce}, \dot{R})_2\dddot{Si} + \dot{H}$.

Hexagonal; 0P; ∞P; in low six-sided prisms. Generally fine-granular; fracture uneven, splintery; brittle. H. = 5·5; G. = 4·9 to 5. Translucent on the edges; dull, adamantine, or resinous. Clove-brown, cherry-red, or pearl-grey. Sol. in h. acid, leaving gelatinous silica. C.c.: 20·5 silica, 73·5 protoxide of cerium (with didymium and lanthanum), and 6 water. Bastnaes near Riddarhyttan.

485. GALMEI, $\dot{Zn}_2\dddot{Si} + \dot{H}$.

Right prismatic, and hemimorphic; $2\breve{P}2$ (*P*) with polar edges 101° 35′ and 132° 26′, ∞P (*d*) 103° 50′, $\bar{P}\infty$ (*o*) 117° 14′, $\breve{P}\infty$ (*l*) 128° 55′ (fig. 46); common form $\infty\breve{P}\infty$ (*s*), ∞P, $\bar{P}\infty$. Also columnar, fibrous, granular, and earthy. Cl. prismatic along ∞P, very perfect; along $\bar{P}\infty$ perfect. H. = 5; G. = 3·3 to 3·5. Transparent to translucent; vitreous and pearly. Colourless or white, but often light grey, also yellow, green, brown, and blue; becomes electric by heat. B.B. decrepitates slightly, but is infusible; with cobalt solution blue and partly green; readily soluble in acids, and gelatinizes. C.c.: 25 silica, 67·5 zinc oxide, and 7·5 water. Wanlockhead, Mendip Hills, Matlock, Raibl and Bleiberg in Carinthia, Aix-la-Chapelle, Iserlohn, Nertchinsk, Pennsylvania, Virginia. Used as an ore of zinc.

WILLEMITE GROUP.

486. WILLEMITE, $\dot{Zn}_2\dddot{Si}$.

Rhombohedral; R 116° 1′. Cl. basal, and prismatic, ∞R; brittle. H. = 5·5; G. = 3·9 to 4·2. White, yellow, brown, and red. Vitreous lustre. C.c.: oxide of zinc 73, silica 27. Altenberg, Liége, Greenland, New Jersey.

487. TROOSTITE, $\dot{Z}n\ddot{S}i + \dot{M}n\ddot{S}i$.

Rhombohedral; R 116°. Cl. prismatic, ∞P2; brittle. H. = 5·5; G. = 4·1. Asparagus-green, grey, and reddish brown. Vitreous. C.c.: oxide of zinc 58, oxide of manganese 13, silica 28. New Jersey.

488. CENTROLITE ($\dot{P}b\dot{M}n$) $\ddot{S}i$.

Right prismatic; ∞P 115° 18′. Form ∞P, P, ∞P̆∞. H. = 5; G. = 6·2. Red-brown. Cl. prismatic; splendent on P. Southern Chili.

489. PHENACITE, $Gl_2\ddot{S}i$.

Hexagonal and tetartohedral; R (p) 116° 36′ (fig. 473). Crystals R, ∞P2, ⅔P2. Twins with parallel axes, and intersecting. Cl. R, and ∞P2; fracture conchoidal. H. = 7·5 to 8; G. = 2·97. Transparent or translucent; vitreous. Colourless, and wine-yellow or brown when fresh, but colour soon lost on exposure. B.B. infusible; not affected by acids. C.c.: glucina 45·8, silica 54·2. Framont in Alsace, Takovaya in Urals, Miask, Durango in Mexico.

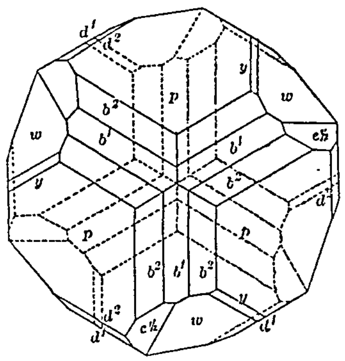


Fig. 473 (sp. 489).

490. DIOPTASE, $\dot{C}u\ddot{S}i + \dot{H}$.

Hexagonal and rhombohedral; R 125° 54′, −2R (r) 95° 28′, ∞P2, −2R$\frac{7}{4}$ (s) (fig. 474). Cl. R, perfect; brittle. H. = 5; G. = 3·2 to 3·3. Transparent or translucent; vitreous. Emerald-green, rarely verdigris-green or blackish green; streak green. C.c.: 38·7 silica, 50 copper protoxide, and 11·3 water. Altyn-Tübeh in the Kirghiz Steppe, Muroshnaya, Copiapo.

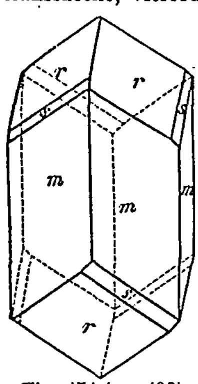


Fig. 474 (sp. 490).

491. CHRYSOCOLLA, $\dot{C}u\ddot{S}i + 2\dot{H}$.

Botryoidal or investing; brittle; fracture conchoidal. H. = 2 to 3; G. = 2 to 2·3. Translucent; resinous. Verdigris- to emerald-green or azure-blue; streak greenish white. C.c.: 34·83 silica, 44·94 copper protoxide, and 20·23 water. Leadhills, Lackentyre in Kirkcudbright, Cornwall, Saxony, Hungary, Spain, Urals, Australia, Chili.

492. BOGOSLOVSKITE (*Kupferblau*).

Massive; fracture conchoidal; brittle. H. = 4 to 5; G. = 2·56. Sky- to ultramarine-blue; streak smalt-blue, and shining. A silicate of copper, with 45·5 per cent. copper oxide. Schapbach Valley in Baden, Bogoslovsk in the Urals. *Demidowite* may be the same.

GARNET GROUP.

493. GARNET, $\dot{R}_3\ddot{S}i_2 + \ddot{\bar{R}}\ddot{S}i$.

Cubic; most common forms ∞O and 2O2 (figs. 33, 40, 60, 475). Also granular. Cl. dodecahedral; fracture conchoidal, or splintery. H. = 6·5 to 7·5; G. = 3·5 to 4·3. Pellucid; vitreous or resinous. Rarely colourless or white; generally red, brown, black, green, or yellow. B.B. in general fuses to a glass, black or grey in those containing much iron, green or brown in the others, and often magnetic; imperfectly soluble in h. acid. C.c. exceedingly variable, but generally forming two series, according as R_2O_3 is chiefly alumina or chiefly iron peroxide; and these are again divided according as RO is more especially lime, iron protoxide, magnesia, or a similar base. The more important varieties are—

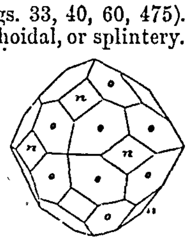


Fig. 475.

(1) *Lime-Alumina Garnet*, $\dot{C}a_3\ddot{S}i_2 + \ddot{\bar{A}}l\ddot{S}i$, with 40 silica, 23 alumina, and 37 lime. To this subdivision belong—

(*a*) *Water Garnet.*—Colourless to white. Craig Mohr, Aberdeen; Thelemark in Norway.

(*b*) *Grossular.*—Olive- to gooseberry-green. Craig Mohr; Wilui river; America.

(*c*) *Cinnamon Stone.*—Hyacinth-red to orange-yellow. Glen Gairn (Aberdeen), Allt Gonolan and Ord Ban (Inverness), Ceylon, Wermland. *Romanzowite*, from Kimito (Finland), is the same. This variety when polished is often sold as *Hyacinth*.

(*d*) *Common Lime Garnet.*—Here one half of the alumina is replaced by iron peroxide. Colours red, brown, yellow. Piedmont, Vesuvius, the Urals.

(2) *Magnesia-Alumina Garnet*; RO chiefly magnesia. Arendal.

(3) *Manganese-Alumina Garnet*; RO = MnO; reddish-brown. Spessart (Bavaria), Sweden.

(4) *Magnesia-Iron-Lime-Alumina Garnet, Pyrope.*—Colour port-wine to purplish red. Elie in Fife, Zöblitz in Saxony, Bohemia.

(5) *Iron-Alumina Garnet, Almandine, Noble Garnet.*—Columbine-red, inclining to violet, blood-red, and reddish brown. Common in mica-slate, gneiss, and granite. Shetland, Ross, Inverness, Aberdeen, Falun, Arendal, Tyrol, the Urals, North America, Pegu, and Ceylon.

(6) *Lime-Chrome-Alumina Garnet*, $\dot{C}a_3\ddot{S}i_2 + (\ddot{\bar{C}}r, \ddot{\bar{A}}l)\ddot{S}i$, *Uwarowite.* Emerald-green; with 22 per cent. chrome oxide. Bissersk and Kyshtimsk in the Urals, India, and California.

(7) *Lime and Iron Garnet*, $\dot{C}a_3\ddot{S}i_2 + \ddot{\bar{F}}e, \ddot{S}i$. This includes—

(*a*) *Common Iron-Garnet, Rothoffite, Allochroite.*—Subtranslucent or opaque. Green, brown, yellow, or black; with white, grey, or yellow streak. Sweden and Arendal.

(*b*) *Melanite.*—Black; opaque; in thin splinters translucent; streak grey; slightly magnetic. Albano near Frascati, Vesuvius, France, Lappmark.

(*c*) *Colophonite.*—Yellowish-brown to pitch-black, also yellow or red; resinous; streak white. G. = 3·43. Arendal.

The red varieties, when cut *en cabochon*, are termed *Carbuncles.*

494. AXINITE, $(\ddot{\bar{A}}l, \ddot{B})\ddot{S}i + 2(\dot{C}a, \dot{F}e)\ddot{S}i$.

Anorthic. Crystals unsymmetrical. *u* : *P* 135° 31′; *u* : *r* 115° 38′, *P* : *r* 134° 45′ (figs. 136, 137). Cl. distinct along planes truncating the sharp edges between *P* and *u* and *P* and *r*. H. = 6·5 to 7; G. = 3·2 to 3·3. Pellucid; vitreous. Clove-brown, inclining to smoke-grey or plum-blue; but often cinnamon-brown in one direction, dark violet-blue in a second, and pale olive-green in a third (*trichroism*). B.B. colours flame green; intumesces, and fuses easily to a dark green glass, becoming black in the ox. flame; not sol. in h. acid till after ignition, when it gelatinizes. C.c.: 45·9 silica, 5·9 boracic acid, 17·5 alumina, 9·3 iron (with manganese) protoxide, and 21·4 lime. Botallack and other mines in Cornwall, Bourg d'Oisans in Dauphiné, Kongsberg, Arendal, Nordmark in Sweden, Pyrenees, St Gotthard, Tyrol, Thum in Saxony, Urals, and North America.

495. DANBURITE $(\dot{C}a, \ddot{B})\, 2\ddot{S}i$.

Right prismatic. ∞P (*I*) 122° 52′, ∞P̆2 (*e*) 94° 52′, P̄∞ (*d*) 97° 7′, 4P̆∞ (*w*) 54° 58′, 0P (*c*), P (*o*), 2P̆2 (*r*), ∞P̄∞ (*a*), ∞P̆4 (*n*).

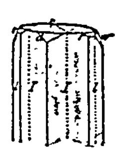


Fig. 476.

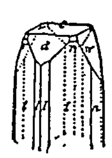


Fig. 477.

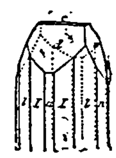


Fig. 478.

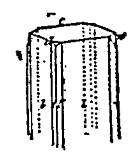


Fig. 479.

Cl. basal; fracture uneven to subconchoidal; vitreous to greasy lustre. H. = 7 to 7·5; G. = 2·986 to 3·021. Pale yellow to reddish brown. Translucent; brittle. C.c.: 22·76 lime, 28·46 boracic acid, 48·76 silica. Danbury in Connecticut, Russell in New York.

HELVINE GROUP.

496. HELVINE, $\dot{M}nS + 3\dot{R}_2\ddot{S}i$.

Cubic and tetrahedral. $\frac{O}{2}$ or $\frac{O}{2} - \frac{O}{2}$ (fig. 64 and with 66). Imbedded or attached. Cl. octahedral. H. = 6 to 6·5; G. = 3·1 to 3·3. Translucent on the edges; resinous. Wax-yellow, siskin-green, or yellowish brown. B.B. in the red. flame fuses with intumescence to a yellow obscure pearl; sol. in h. acid, evolving sulphuretted hydrogen, and gelatinizes. C.c.: 34 silica, 10 glucina, 8 iron protoxide, 43 manganese protoxide, and 5 sulphur. Schwarzenberg in Saxony, and near Modum in Norway.

497. DANALITE, $3\dot{R}_2\ddot{S}i + ZnS$.

Cubic. In octahedra, with striated dodecahedral planes. H. = 5·5 to 6; G. = 3·43. Vitreous to resinous. Flesh-red to grey; streak lighter. Translucent; brittle. C.c.: protoxide of iron 29, of manganese 6·5, of zinc 19, silica 31·5, sulphur 5·5. Rockport in Massachusetts.

498. EULYTINE, $\ddot{B}i_2\ddot{S}i_3$.

Cubic and tetrahedral. $\frac{2O2}{2}$ and $-\frac{2O2}{2}$. The crystals (fig. 66) small, and often with curved faces; fracture conchoidal. H. = 4·5 to 5; G. = 5·9 to 6·1. Transparent and translucent; adamantine. Clove-brown, yellow, grey, or white; streak white or grey. C.c.: 16·2 silica and 83·8 bismuth peroxide. Schneeberg and Bräunsdorf near Freiberg.

Scapolite Group.

499. Sarcolite, $8\dot{C}a$, $3\dddot{A}l$, $\dot{N}a$, $9\dddot{S}i$.

Pyramidal. P 102° 54′; ∞P∞; 0P; P, and other faces as in fig. 480, many of the faces being alternately hemihedral. H. = 5·5 to 6; G. = 2·93. Vitreous. Grey to rose-red. Translucent; very brittle. C.c.: alumina 21·5, lime 32·4, soda 3·3, silica 40·5. B.B. fuses to a white enamel; gelatinizes with acids. Somma.

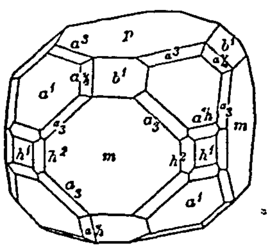


Fig. 480 (sp. 499).

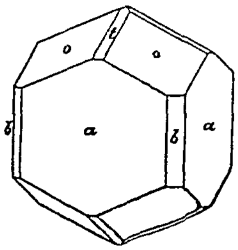


Fig. 481 (sp. 500).

500. Meionite, $6(\dot{C}a, \dot{N}a)$, $4\dddot{A}l$, $9\dddot{S}i$.

Pyramidal. P (*o*) 63° 42′; P∞ (*t*); ∞P (*a*); ∞P (*b*) (fig. 481). Cl. macrodiagonal. H. = 5·5 to 6; G. = 2·6 to 2·74. Vitreous. Colourless or white. Transparent. Much cracked. C.c.: 31·9 alumina, 26·2 lime, 41·9 silica. Gelatinizes in acids. Somma.

501. Mizzonite, $6(\dot{C}a, \dot{N}a)$, $4\dddot{A}l$, $15\dddot{S}i$.

Pyramidal; P 64° 4′ (fig. 482). Similar to meionite. C.c.: alumina 23·8, lime 8·8, soda 9·8, silica 54·7. Insoluble in h. acid. Somma.

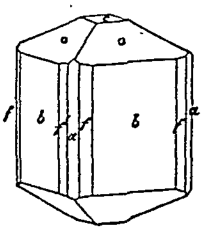


Fig. 482 (sp. 501).

502. Scapolite, $3(\dot{C}a, \dot{N}a)\dddot{S}i + \dddot{A}l_2\dddot{S}i_3$.

Pyramidal. P 63° 42′; ∞P∞; P; ∞P; also massive. Cl. ∞P∞, perfect; and ∞P. H. = 5 to 5·5; G. = 2·6 to 2·8. Transparent or translucent; vitreous, pearly, or resinous. Colourless, but also pale grey, green, yellow, or red. B.B. melts with effervescence to a vesicular glass; in the closed tube may show traces of fluorine; with solution of cobalt becomes blue. Sol. in h. acid. C.c.: 49 silica, 28 alumina (with iron peroxide), and 23 lime (with soda). Tiree (Scotland), Arendal, Tunaberg, Pargas, Massachusetts, and New York. Known by its rectangular cleavage, resinous lustre on fractured surfaces, and action B.B. *Dipyre*, P 64° 4′, is a variety.

503. Mellilite (*Humboldtilite*), $2(\dot{C}a, \dot{M}g)\dddot{S}i_2 + (\dddot{A}l, \dddot{F}e)\dddot{S}i$.

Pyramidal. P 65° 30′; 0P; ∞P∞. Cl. basal, perfect. H. = 5 to 5·5; G. = 2·91 to 2·95. Translucent on edges; vitreous to resinous. Honey-yellow, orange-brown, and yellowish white. C.c.: 32 lime, 7 magnesia, 9 alumina, 7 iron peroxide, 40 silica. Capo di Bove, and Vesuvius.

504. Gehlenite, $(\dot{C}a, \dot{F}e)_3\dddot{S}i + (\dddot{A}l, \dddot{F}e)\dddot{S}i$.

Pyramidal. P. 59°; 0P; ∞P∞; ∞P3; 2P. Cl. basal. H. = 5·5 to 6; G. = 2·9 to 3·1. Translucent on edges. Dull resinous. Mountain-, leek-, or olive-green, and liver-brown. C.c.: 22 alumina, 5 iron peroxide, 35 lime, 4 magnesia, 31·4 silica. Monzoni in the Fassa Valley.

Nepheline Group.

505. Leucite, $\dddot{A}l$, $\dddot{S}i_3 + \dot{K}\dddot{S}i$.

Pyramidal. Combination of the ditetragonal pyramid (*i*) with the tetragonal pyramid (*o*), and 2P∞ (*u*) with ∞P (*m*). Hemitropes united

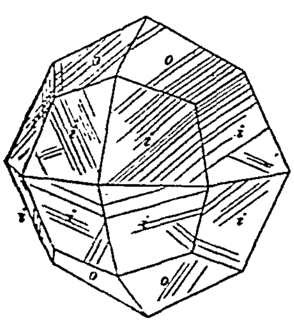


Fig. 483.

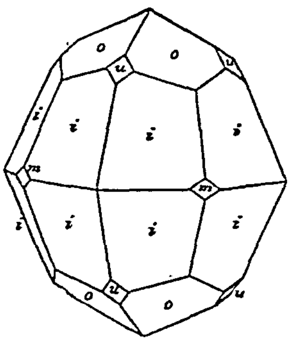


Fig. 484.

by (*u*). Fracture conchoidal. H. = 5·5 to 6; G. = 2·4 to 2·5. Transparent to translucent on the edges; vitreous, inclining to resinous. Colourless, but greyish, yellowish, or reddish white; streak white. B.B. infusible; with cobalt solution becomes blue. Sol. in h. acid, without gelatinizing. C.c.: 54·9 silica, 23·6 alumina, and 21·5 potash. Abundant in the lavas of Vesuvius, the tufas near Rome, and the peperino of Albano; also at the Kaiserstuhl, and near Lake Laach. Readily distinguished from analcime by its infusibility, and by never showing faces of the cube.

506. Nepheline (*Elæolite*), $\dddot{A}l\dddot{S}i + 4(\dot{N}a, \dot{K})\dddot{S}i$.

Hexagonal. P 88° 10′. ∞P, 0P, P common; also fig. 485. Crystals imbedded, or in druses; also massive-granular; fracture conchoidal, or uneven. H. = 5·5 to 6; G. = 2·58 to 2·64. Transparent or translucent; vitreous and resinous. Colourless or white (nepheline); or opaque, dull resinous, and green, red, or brown (elæolite). B.B. melts difficultly (nepheline), or easily with slight effervescence (elæolite), into a vesicular glass. Sol. and gelatinizes in h. acid. C.c.: 41·2 silica, 35·3 alumina, 17 soda, 6·5 potash. Nepheline at Monte Somma, Capo di Bove, Katzenbuckel in the Odenwald, Aussig, and Lusatia. Elæolite in the zircon syenite at Laurvig, Fredriksvärn, Brevig, and Miask.

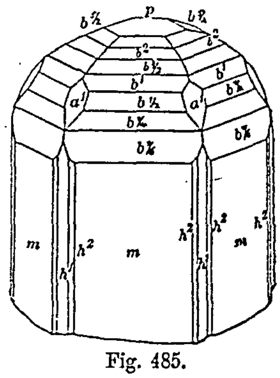


Fig. 485.

Davine, with ½P 51° 46′, seems only a variety; as also *Cancrinite*, bright blue, and with some carbonate of lime.

507. Microsommite, $\dot{K}\dddot{S}i + \dddot{A}l\dddot{S}i + NaCl$.

Hexagonal. ∞P; 0P; ∞P2; ∞P$\frac{3}{2}$. Cl. ∞P. H. = 6; G. = 2·42 to 2·53. Colourless to yellow; lustre silky. Somma and Vesuvius.

508. Sodalite, $3(\dddot{A}l\dddot{S}i + \dot{N}a\dddot{S}i) + NaCl$.

Cubic; ∞O, and fig. 486; generally distorted; also massive and granular. Cl. ∞O; fracture conchoidal or uneven. H. = 5·5; G. = 2·13 to 2·29. Translucent; vitreous. White, grey, and rarely green or blue. C.c.: 37 silica, 31·8 alumina, 19·2 soda, 4·7 sodium, and 7·3 chlorine. Greenland, Vesuvius, Ilmen Hills, Fredriksvärn, and Litchfield in Maine.

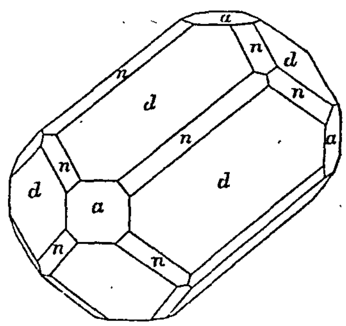


Fig. 486 (sp. 508).

509. Nosean, $3(\dddot{A}l\dddot{S}i + \dot{N}a\dddot{S}i) + \dot{N}a\dddot{S}$.

Cubic; and granular. H. = 5·5; G. = 2·28 to 2·40. Translucent; vitreous to resinous. Ash or yellowish grey, sometimes blue, brown, or black. C.c.: 36 silica, 31 alumina, 25 soda, and 8 sulphuric acid. Lake Laach, and Rieden near Andernach, on the Rhine. Occurs in phonolites, in minute crystals.

510. Hauyne, $2(\dddot{A}l\dddot{S}i + \dot{N}a\dddot{S}i) + \dot{C}a\dddot{S}$.

Cubic; chiefly ∞O; also fig. 487; but more common in grains. Cl. ∞O. H. = 5 to 5·5; G. = 2·4 to 2·5. Semitransparent or translucent; vitreous or resinous. Azure- or sky-blue; streak bluish white. C.c.: 34·2 silica, 28·5 alumina, 11·5 soda, 4·3 potash, 10·4 lime, and 11·1 sulphuric acid. Vesuvius, Mount Vultur near Melfi, the Campagna of Rome, and Niedermendig near Andernach.

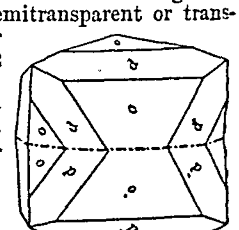


Fig. 487 (sp. 510).

511. Lapis-Lazuli.

Cubic; O∞; generally massive, granular. H. = 5·5; G. = 2·38 to 2·42. Translucent on edges; dull resinous or vitreous. Ultramarine, or azure-blue; streak light blue. B.B. fuses readily to a white porous glass. In h. acid the powder is dissolved and gelatinizes, evolving sulphuretted hydrogen. C.c.: 45·50 silica, 5·89 sulphuric acid, 31·76 alumina, 9·09 soda, 3·52 lime, 0·86 iron, 0·42 chlorine, 0·95 sulphur, 0·12 water. Near Lake Baikal, China, Tibet, Tartary, Monte Somma, and Chili. It is used for ornamental purposes, and in the preparation of ultramarine. The colour both in it and hauyne seems due to some compound of sulphur with sodium and iron.

Mica Group.

512. Biotite (*Magnesia-Mica*), $\dddot{A}l_2\dddot{S}i_3 + (\dot{M}g, \dot{K}, \dot{F}e)_2\dddot{S}i_3$.

Oblique prismatic, C 89° 59′. 0P (*c*), 98° 41′ P (*m*), −½P (*o*), ∞P^c∞ (*b*), P̆∞ (*r*), −$\frac{2}{3}$P^{c}3 (*z*). Cl. basal, perfect; sectile; thin plates elastic. H. = 2·5 to 3; G. = 2·85 to 2·9. Transparent, but often only

in very thin plates. Generally uniaxal, sometimes with divergence = 56°. Metallic, pearly. Usually dark green, brown, or black; streak greenish grey or white. B.B. difficultly fusible to a grey or black glass. Completely sol. in concentrated s. acid, leaving white

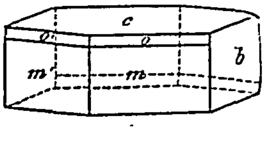


Fig. 488.

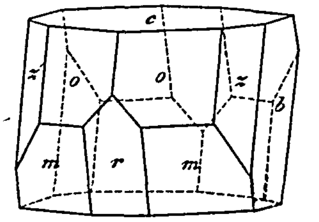


Fig. 489.

pearly plates of silica. C.c.: 39 silica, 17 alumina, 10 iron protoxide, 20 magnesia, 9 potash. Hillswick, Shetland, in gneiss; Sutherland, Ross, Inverness, in limestone; Skye and Fife in trap; Pargas, Bodenmais, Greenland, New York. *Rubellan* is a decomposed variety.

513. Haughtonite, $(\dddot{\mathrm{A}}\mathrm{l},\dddot{\mathrm{F}}\mathrm{e})\ddot{\mathrm{S}}\mathrm{i}+(\dot{\mathrm{F}}\mathrm{e},\dot{\mathrm{K}})_2\ddot{\mathrm{S}}\mathrm{i}$.

Oblique prismatic. Cl. basal, perfect. H. = 3; G. = 3·1. Vitreous to adamantine. Chocolate-brown to black. Weathers pale green and ochry. Difficultly soluble in acids. B.B. fused with difficulty to a highly magnetic bead. C.c.: silica 36, alumina 18, ferric oxide 4·5, ferrous oxide 18, magnesia 9, potash 8, water 3. Common in the granites of Scotland. Black Forest, Harzburg, Tyrberger.

514. Lepidomelane, $(\dddot{\mathrm{A}}\mathrm{l},\dddot{\mathrm{F}}\mathrm{e})\ddot{\mathrm{S}}\mathrm{i}+(\dot{\mathrm{F}}\mathrm{e},\dot{\mathrm{K}})\ddot{\mathrm{S}}\mathrm{i}$.

Oblique prismatic. Cl. basal, perfect; brittle. H. = 3; G. = 2·97. Vitreous; transparent to opaque. Rich brown to raven-black. B.B. fuses easily to a black feebly-magnetic bead. Sol. in h. acid, leaving pearly scales of silica. C.c.: 37 silica, 17 alumina, 24 iron peroxide, 3 protoxide of iron, 8 potash, 10 magnesia, 4 water. Rarely in gneiss, Scotland; common in granite, Ireland; and Persberg, Sweden.

515. Anomite, $12\dot{\mathrm{M}}\mathrm{g}$, $3\dddot{\mathrm{A}}\mathrm{l}$, $2\dot{\mathrm{K}}$, $\dot{\mathrm{H}}$, $12\ddot{\mathrm{S}}\mathrm{i}$.

Oblique prismatic. $c:m$ 98° 42′. Form c, m, o, b (see fig. 488); divergence of optic axes 12° to 13°. Monroe (New York), Lake Baikal.

516. Phlogopite, $(\frac{3}{5}\dot{\mathrm{R}}_3+\frac{1}{5}\dddot{\mathrm{R}})\ddot{\mathrm{S}}\mathrm{i}_3$.

Oblique prismatic. 0P (c), P (m), $-\frac{1}{2}$P (o), ∞P∞ (b). $c:m$ 98° 30′ to 99°. Cl. basal, perfect. H. = 2·5 to 3; G. = 2·75 to 2·97. Pearly to submetallic. Yellowish brown with copper-like reflexion; also green, white, and colourless. Transparent. Divergence of optic axes 3° to 20°. C.c.: 14 alumina, 2 protoxide of iron, 28 magnesia, 8·6 potash, 2·57 fluorine, 41 silica. B.B. whitens, and fuses on edges. Decomposed by s. acid, leaving the silica in scales. Pargas (Finland), Fassa Valley, New York, Canada, Ceylon. Characteristic of serpentine and of dolomitic limestones.

517. Zinnwaldite.

Oblique prismatic. Forms as in figs. 490, 491; also $2\bar{\mathrm{P}}\infty$ (H) and $3\mathrm{P}^c3$ (x). $m:c$ 98° to 99°. Divergence of optic axes 65°. G. = 2·82 to 3·2. C.c. similar to muscovite (sp. 519), but with 4 to

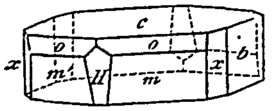


Fig. 490.

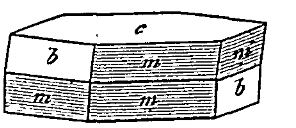


Fig. 491.

8 fluorine, 2 to 5 lithia, and traces of rubidium, cæsium, and thallium. Altenberg and Zinnwald, St Just and Trewavas in Cornwall. *Cryophyllite* from Cape Ann in Massachusetts is similar.

518. Lepidolite.

Oblique prismatic. Forms like muscovite. Divergence of optic axes 50° to 77°. Cl. basal, perfect. H. = 2·5 to 4; G. = 2·84 to 3. Often massive; scaly granular, coarse or fine. Lustre pearly. Colour rose-red, violet, lilac, yellow, greyish white. Contains 5 to 6 per cent. lithia, with rubidium, cæsium, and thallium, also fluorine. B.B. colours flame red. Mourne Mountains, Rozena (Moravia), Utö (Sweden), Ekaterinburg, Maine.

519. Muscovite (*Muscovy-Glass*), $3\dddot{\mathrm{A}}\mathrm{l}\ddot{\mathrm{S}}\mathrm{i}+\dot{\mathrm{K}}\ddot{\mathrm{S}}\mathrm{i}$.

Right prismatic, with monoclinic habit. 0P (c); ∞P (M); $\infty\mathrm{P}^c\infty$ (b); P (m); $2\mathrm{P}^c\infty$ (y). ∞P nearly 120°. Twin-face c. Cl. basal, perfect; elastic. Angle of optic divergence from 44° to 77°. Metallic, pearly. Colourless, and tinged of various shades to black. B.B. fuses to an opaque enamel. Not affected by acids. C.c.: 36·6 alumina, 11·8 potash, 45·1 silica, 4·5 water, with traces of fluorine. Shetland, Loch Glass in Sutherland, Glen Skiag (crystals 15 inches in length) and Struay Bridge in Ross, Aberdeen, Cornwall, St Gotthard, Norway, Sweden, Siberia. Crystals over a yard in diameter in China, where it is used for windows. *Fuchite*, bright green, has 6 per cent. of chrome oxide. *Margarodite* contains 4 to 6 water. *Gilbertite*, Cornwall, may be different.

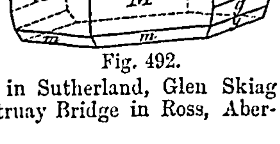


Fig. 492.

520. Paragonite (*Soda-Mica*), $3\dddot{\mathrm{A}}\mathrm{l}_2\ddot{\mathrm{S}}\mathrm{i}_3+(\dot{\mathrm{N}}\mathrm{a},\dot{\mathrm{H}})\ddot{\mathrm{S}}\mathrm{i}$.

Massive; foliated. Lustre pearly. H. = 2·5 to 3; G. = 2·78 to 2·9. Yellowish, greyish, and greenish. C.c.: 40·1 alumina, 6·1 soda, 47·75 silica, 4·6 water. Monte Campione, St Gotthard.

521. Sandbergerite (*Baryta-Mica*).

White minute scaled aggregates. G. = 2·894. C.c.: 30·2 alumina, 4·9 magnesia, 5·9 baryta, 7·6 potash, 42·6 silica, 4·43 water. Pfitsch Valley in Tyrol, and the Swiss Alps.

522. Margarite (*Lime-Mica*).

Right prismatic. Cl. basal perfect. H. = 3·5 to 4·5; G. = 2·99 to 3·1. Lustre of cl. pearly. Lateral planes, vitreous. Snow-white, reddish white, and pearl-grey. Laminæ brittle. Optic axial angle 109° to 129°. C.c.: 51·2 alumina, 11·6 lime, 2·6 soda, 30·1 silica, and 4·5 water. Greiner in Tyrol, Naxos, Asia Minor, Greece, Pennsylvania, North Carolina. *Diphanite* is similar.

523. Euphyllite $(\frac{1}{5}\dot{\mathrm{R}}_3+\frac{4}{5}\dddot{\mathrm{R}})_2\ddot{\mathrm{S}}\mathrm{i}_3+\frac{4}{5}\dot{\mathrm{H}}$.

Like muscovite, but laminæ not easily separable. H. = 3·5 to 4·5; G. = 2·83 to 3. Lustre of cl. pearly to adamantine. White to colourless. Transparent to opaque. Laminæ brittle. Optic axial angle 71½°. C.c.: alumina 42·3, lime 1·5, potash 3·2, soda 5·9, silica 41·6, water 5·5. Unionville in Pennsylvania.

524. Clintonite, $(\frac{3}{4}\dot{\mathrm{R}}_3+\frac{7}{4}\dddot{\mathrm{A}}\mathrm{l})_2\ddot{\mathrm{S}}\mathrm{i}+\frac{1}{2}\dot{\mathrm{H}}$.

Oblique prismatic; in hexagonal tables, or massive foliated. Cl. basal, perfect. H. = 5 to 5·5; G. = 3·15. Translucent; pearly to metallic on the cleavage. Angle of the optic axes 3° to 13°. Reddish brown to yellow. C.c.: 39·7 alumina, 21·1 magnesia, 13·1 lime, 19·2 silica, 2 protoxide of iron, 4·9 water. Amity and Warwick in New York. *Brandisite* is similar.

525. Xanthophyllite.

Oblique prismatic, C about 90°. Crystalline aggregates. Radiate lamellar. H. = 4·5 to 6; G. = 3·1. Lustre pearly. Colour yellowish to copper-red. Angle of optic axes 0° to 20°. C.c.: alumina 43·6, lime 13, magnesia 17·5, silica 16·9, water 5·1. Zlatoust.

526. Chloritoid, $\dot{\mathrm{F}}\mathrm{e}\ddot{\mathrm{S}}\mathrm{i}+\dddot{\mathrm{A}}\mathrm{l}\dot{\mathrm{H}}$.

Right prismatic; in foliated crystals; brittle. Cl. basal. Lustre greasy to pearly. H. = 5·5 to 6; G. = 3·52 to 3·56. Dark green; streak greenish white. C.c.: 40 alumina, 27 protoxide of iron, 25 silica, 7 water. *B.B. infusible, but becomes magnetic.* Decomposed by s. acid. Hillswick in Shetland, Pregratten in Tyrol, Ekaterinburg, Canada.

527. Masonite.

Broad plates. H. = 6·5; G. = 3·53. Grey-green. Streak grey. Pearly to vitreous. C.c.: 26·4 alumina, 19 peroxide of iron, 16·7 protoxide of iron, 32·68 silica, 4·5 water. Middletown in Rhode Island.

528. Ottrelite, $\dddot{\mathrm{A}}\mathrm{l}_2\ddot{\mathrm{S}}\mathrm{i}_3+3(\dot{\mathrm{F}}\mathrm{e},\dot{\mathrm{M}}\mathrm{n})\ddot{\mathrm{S}}\mathrm{i}+3\dot{\mathrm{H}}$.

Thin hexagonal tables. Cl. parallel to the prismatic faces. H. = 5·5; G. = 4·4. Translucent; vitreous. Greenish or blackish grey. C.c.: 24·3 alumina, 16·8 protoxide of iron, 11·1 protoxide of manganese, 43·4 silica, 5·65 water. Ottrez in the Ardennes (Luxemburg), Aste in the Pyrenees, Ebnat in Bavaria, Newport (Rhode Island), Vardhos (Greece).

529. Pyrosmalite, $7\dot{\mathrm{R}}\ddot{\mathrm{S}}\mathrm{i}+\mathrm{RCl}_2+5\dot{\mathrm{H}}$.

Hexagonal. P 101° 34′; crystals ∞P, 0P; tabular; also granular. Cl. basal, perfect; brittle. H. = 4 to 4·5; G. = 3 to 3·2. Translucent to opaque; resinous, or metallic-pearly. Liver-brown to olive-green. C.c.: 35·5 silica, 27·5 iron protoxide, 21·5 manganese protoxide, 8 chloride of iron or manganese, and 7·5 water. Nordmark in Sweden.

530. Astrophyllite, $(\dot{\mathrm{R}}_3,\dddot{\mathrm{R}})_2\ddot{\mathrm{S}}\mathrm{i}_3$.

Right prismatic, with oblique habit. In long tabular prisms, and in stellate groups. Cl. basal, perfect. H. = 3·5; G. = 3·33. Submetallic to pearly. Tombac-brown to gold-yellow. Pellucid. Axial divergence 118° to 124°. C.c.: peroxide of iron 9·3, protoxide 23·6, protoxide of manganese 10, soda 3·9, potash 5·9, titanic acid 7·90, silica 39·2. Brevig, El Paso in Colorado.

Chlorite Group.

531. Chlorite, $2\dot{\mathrm{R}}\ddot{\mathrm{S}}\mathrm{i}+\dot{\mathrm{R}}_2\dddot{\mathrm{A}}\mathrm{l}+3\dot{\mathrm{H}}$.

Hexagonal. P 106° 50′; crystals tabular of 0P, ∞P or 0P, P (fig. 493); often in comb-like or other groups; generally foliated and scaly. H. = 1 to 1·5; G. = 2·78 to 2·96. Leek-green to blackish green; streak greenish grey. C.c.: 21 alumina, 20 protoxide of iron, magnesia 18, silica 24, water 11. Tarfside, Bute, and Jura in Scotland. Cornwall, Cumberland, Wales, Fassa Valley, Urals, America.

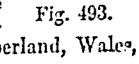


Fig. 493.

532. Pennine, $4\dot{M}g\ddot{S}i+\dot{M}g_3\ddot{A}l+5\dot{H}$.

Hexagonal, rhombohedral; R 65° 28′. Crystals chiefly very acute rhombohedrons, with or without the base. Lustre resinous. H. = 2 to 3; G. = 2·6 to 2·77. Streak greenish white. B.B. exfoliates, becomes white, and fuses on the edges to a white enamel. Completely sol. in warm s. acid. C.c.: 33·6 silica, 14·4 alumina, 39·4 magnesia, and 12·6 water; but with 5 to 6 iron protoxide replacing magnesia. Scalpa in Harris, Glen Lochy in Perthshire, Zermatt in Valais, Tyrol, Ala di Stura in Piedmont, Mauléon in the Pyrenees. *Leuchtenbergite* is the same. *Kämmererite*, with 5 to 8 chromium sesquioxide, is violet-blue or green; Unst, Siberia, Pennsylvania. *Rhodochrome* and *Tabergite* are also varieties.

533. Clinochlore (*Ripidolite*), $3\dot{M}g\ddot{S}i+\dot{M}g_3\ddot{A}l+4\dot{H}$.

Oblique prismatic, C. 76° 4′. ∞P 121° 28′. 0P : P 113° 59′; 0P : ∞P 192° 8′. Crystals −2P, P, 4P∞, 0P (*n*, *m*, *t*, P, fig. 494). Twins common; lustre vitreous or resinous. H. = 2 to 3; G. = 2·6 to 2·8. B.B. becomes white, and fuses on thin edges to a greyish yellow enamel. C.c.: 30·3 silica, 17·3 alumina, 40·3 magnesia, and 12·1 water. Edentian and Blair Athole in Scotland, Traversella in Piedmont, Akhmatovsk in Urals, West Chester in Pennsylvania. *Corundophyllite*, *Epichlorite*, and *Kotschubeyite* are varieties.

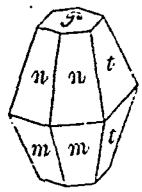


Fig. 494.

534. Pyrosclerite, $(\frac{2}{3}\dot{R}, \frac{1}{3}\ddot{R})_3\ddot{S}i_3+3\dot{H}$.

Right prismatic. Cl. basal, perfect; fracture uneven; brittle; sectile. H. = 3; G. = 2·7 to 2·8. Pearly; translucent. Apple-, emerald-, and grey-green. C.c.: alumina 13·4, chrome oxide 1·4, protoxide of iron 3·5, magnesia 31·6, silica 37, water 11. Porto-Ferraio in Elba, China.

535. Chonicrite.

Massive; crystalline-granular and globular-radiated. H. = 2·5 to 3; G. = 2·91. Weak silky. White, with yellowish spots; greenish blue. C.c.: 17·1 alumina, 22·6 magnesia, 12·6 lime, 35·7 silica, 9 water. B.B. fuses easily, with intumescence, to a grey glass. Decomposed by h. acid, with separation of silica. Colmonell (Ayrshire), Porto-Ferraio.

536. Pycnotrop.

Large grained aggregates. Cl. along two rectangular faces; fracture hackly, splintery. Greyish white to brown-red. Vitreous to greasy. H. = 2 to 2·3; G. = 2·6 to 2·7. C.c.: alumina 29·3, magnesia 12·6, potash 4·4, silica 45, water 7·8. Waldheim in Saxony.

537. Thuringite, $(\frac{1}{2}\dot{R}, \dot{H}_3+\frac{1}{2}(\ddot{A}l, \ddot{F}e))_4\ddot{S}i_3+4\dot{H}$.

Massive; scaly. H. = 2 to 2·5; G. = 3·2. Pearly. Olive-green to pistachio-green; streak paler. Very tough. Powder greasy. C.c.: alumina 16, peroxide of iron 14, protoxide of iron 33, silica 23, water 11. Schmiedefeld in Thuringia, Harper's Ferry on the Potomac, Hot Springs in Arkansas.

538. Delessite, $(\dot{F}e\frac{1}{4}, \dot{M}g\frac{3}{4})_2\ddot{S}i_2+(\ddot{A}l\frac{11}{15}, \ddot{F}e\frac{9}{15})\ddot{S}i+3\dot{H}+2\dot{M}g\dot{H}$.

Massive; scaly. H. = 2 to 2·5; G. = 2·6 to 2·89. Olive-green to dark green, passing to dark brick-red; streak light green. C.c.: alumina 16·3, protoxide of iron 12·6, magnesia 21, silica 31·5, water 15·8. Common in igneous rocks of Old Red Sandstone and Coal-measure age in Scotland. Oberstein, Zwickau, Lagrève near Mielin.

539. Cronstedtite, $\ddot{F}e\ddot{S}i+(\dot{F}e, \dot{M}g)_3\ddot{S}i+3\dot{H}$.

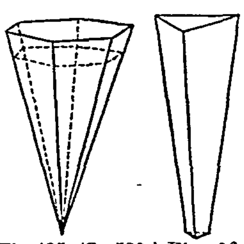


Fig. 495. (Sp. 539.) Fig. 496.

Rhombohedral; radiated columnar. In tapering hexagons, and hemihedral (figs. 495, 496). Cl. basal, perfect; elastic. H. = 2·5; G. = 3·3 to 3·5. Vitreous. Coal-black and brownish black; streak dark olive-green. C.c.: protoxide of iron 39, peroxide of iron 29, silica 22, water 11. Huel Maudlin in Cornwall, Przibram, Brazil (*Sideroschisolite*).

Talc and Serpentine Group.

540. Talc, $\dot{M}g_3\ddot{S}i_4+\dot{H}$.

Right prismatic (?); rarely found in six-sided or rhombic tables; generally massive, granular, or scaly. Rarely fibrous. Cl. basal, perfect; soft, sectile, and flexible in thin plates. H. = 1; G. = 2·6 to 2·8. Transparent in thin plates, and optically binaxal; pearly or resinous. Colourless, but generally greenish or yellowish white to apple- or olive-green. Feels very greasy. B.B. emits a bright light, exfoliates, and hardens (H. = 6), but is infusible; with cobalt solution becomes red. Not sol. in h. or s. acid before or after ignition. C.c.: 63·5 silica, 31·7 magnesia, and 4·8 water. Unst in Shetland, green; Cairnie in Aberdeenshire, brown; Greiner in Tyrol, Sala and Falun, the Pyrenees. Used as crayons, also for forming crucibles and for porcelain.

Steatite.—Massive. Grey, red, yellow, or green. Shetland, Sutherland, Portsoy, and near Kirkcaldy, Scotland; the Lizard Point, Cornwall; Briançon, Wunsiedel. Savage nations cut the steatite into culinary utensils.

Potstone is a mixture of talc, chlorite, and other minerals.

541. Picrophyll, $3\dot{R}\ddot{S}i+2\dot{H}$.

Right prismatic. H. = 2·5; G. = 3·75. Dark green. Foliated, shining. C.c.: magnesia 30·1, protoxide of iron 6·9, silica 49·8, water 9·8. Sala in Sweden.

542. Picrosmine, $2\dot{M}g\ddot{S}i+\dot{H}$.

Right prismatic, but massive. Cl. ∞P̆∞ perfect, less so in other directions; sectile. H. = 2·5 to 3; G. = 2·5 to 2·7. Translucent or opaque; vitreous, but pearly on ∞P̆∞. Greenish white, grey, or blackish green; streak colourless. Yields a bitter odour when breathed on; hence the name. C.c.: 55·8 silica, 36·1 magnesia, and 8·1 water. Presnitz in Bohemia, and Greiner in Tyrol.

543. Monradite, $4(\frac{4}{5}\dot{M}g, \frac{1}{5}\dot{F}e)\ddot{S}i+\dot{H}$.

Massive, foliated, translucent, and yellowish-grey. H. = 6; G. = 3·27. C.c.: silica 55·2, magnesia 31·9, protoxide of iron 8·8, water 4·1. B.B. infusible. Bergen in Norway.

544. Meerschaum, $2\dot{M}g_2\ddot{S}i_3+4\dot{H}$.

Fracture earthy; sectile. H. = 2 to 2·5; G. = 0·8 to 1 (when moist nearly 2). Opaque, dull. Yellowish and greyish white; streak slightly shining. Feels rather greasy, and adheres strongly to the tongue. C.c.: 54·2 silica, 24·7 magnesia, and from 9 to 21·7 water. Negropont, Anatolia, near Madrid and Toledo, Moravia, Wermland.

545. Aphrodite, $4\dot{M}g\ddot{S}i+\dot{H}$.

Soft and earthy. G. = 2·21. Milk-white; opaque. C.c.: 52·9 silica, 35·3 magnesia, 11·9 water. Långbau (Sweden), Elba.

546. Spadaite, $\dot{M}g_5\ddot{S}i_6+4\dot{H}$.

Massive; fracture splintery; sectile. H. = 2·5. Translucent; resinous. Red, with white streak. C.c.: 57 silica, 31·6 magnesia, 11·4 water. Capo di Bove near Rome.

547. Gymnite.

Massive. H. = 2 to 3; G. = 1·9 to 2·2. Translucent; resinous. Dull orange-yellow. C.c.: 41 silica, 37 magnesia, 22 water. Tyrol, Passau, Texas, Barehills near Baltimore. *Nickel Gymnite* has 29 of nickel oxide, replacing the water. Unst, Texas, Pennsylvania.

548. Saponite, $(\dot{F}e\dot{C}a\dot{M}g)_6\ddot{S}i_6+(\ddot{A}l_3\ddot{F}e)\ddot{S}i+13\dot{H}$.

Massive; sectile, and very soft. H. = 1·5; G. = 2·2 to 2·3. White, orange-yellow, pale green, and reddish brown. Feels greasy; does not adhere to the tongue; falls to pieces in water. C.c.: silica 40·8, alumina 7·5, ferric oxide 3·9, magnesia 20·6, water 22·7. Occurs in all the above colours in the later igneous rocks of Scotland, commonly. Lizard Point and St Clear in Cornwall, and Dalecarlia in Sweden. *Pimelite* has 2·8 oxide of nickel.

549. Serpentine, $2\dot{M}g\ddot{S}i+\dot{M}g\dot{H}_3$.

Crystallization uncertain; pseudomorphic after olivine, &c.; generally massive, and granular or fibrous; fracture flat-conchoidal, uneven, or splintery; sectile, and slightly brittle. H. = 3 to 3·5; G. = 2·5 to 2·7. Translucent to opaque; dull resinous. Green, grey, yellow, red, or brown; often in spots, stripes, or veins; streak white, shining. Feels greasy, and does not adhere to the tongue. In the closed tube yields water, and becomes black. C.c.: 43·5 silica, 43·5 magnesia, and 13 water; but with 1 to 8 iron protoxide, and also carbonic acid, bitumen, and chrome oxide.

Varieties are—(1) *Noble Serpentine*, brighter coloured, $16H_2O$, and more translucent; (2) *Picrolite*, or fibrous (H. = 3·5 to 4·5); (3) *Common*, or compact; (4) *Chrysotile* (*Baltimorite*, *Metaxite*), in fine asbestiform fibres, easily separated, with a metallic or silky lustre (G. = 2·219).

Common in Shetland, Urquhart, Portsoy, Ballantrae; Lizard Point in Cornwall; Norway, Sweden, North America. Chrysotile at Colafirth and Fetlar, Shetland, Portsoy, Towanreiff, in Scotland; Reichenstein in Silesia, the Vosges Mountains, and North America. Serpentine is often a product of decomposition, or pseudomorph of various minerals, as augite, hornblende, olivine, spinel, enstatite, garnet, &c. It forms whole rocks and mountains, and is manufactured into various ornamental articles.

550. Marmolite, $3\dot{M}g\ddot{S}i+2\dot{M}g\dot{H}_2$.

Oblique prismatic; often foliated. H. = 2·5 to 3; G. = 2·41 to 2·47. Lustre pearly. Greenish white, bluish white, and asparagus-green. C.c.: silica 42·1, magnesia 38·5, water 17·5. In veins in serpentine of Urquhart and Portsoy (Scotland) Cornwall, Finland, Hoboken.

551. Antigorite.

Thin flat laminæ. H. = 2·5; G. = 2·6. Translucent. Green with brown spots; streak white. C.c.: silica 40·8, magnesia 36·3, protoxide of iron 5·8, water 12·4. Antigorio in Piedmont.

552. HYDROPHITE, $(\dot{M}g, \dot{F}e)_4\ddot{S}i_3 + 4\dot{H}$.

Massive and fibrous. H. = 3 to 4; G. = 2·65. Mountain-green to blue-black; streak paler. C.c.: silica 36·2, magnesia 21·1, protoxide of iron 22·7, water 16. Taberg in Sweden, New York.

553. VILLARSITE, $2\dot{M}g_2\ddot{S}i + \dot{H}$.

Right prismatic; crystals P, 0P, meeting at 136° 32′, often twins in triple combination; also granular. H. = 3; G. = 2·9 to 3. Translucent. Greenish to greyish yellow. C.c.: silica 39·6, magnesia 47·4, protoxide of iron 3·6, water 5·8. Totaig, Ross-shire; Traversella, Piedmont; Forez, France.

554. PYRALLOLITE.

Oblique prismatic, C 72° 56′; columnar and granular. Cl. basic and hemidomatic, meeting at 94° 36′; fracture splintery; brittle. H. = 3·5 to 4; G. = 2·6. Translucent on edges; resinous. Greenish to yellow-grey. C.c.: silicate of magnesia and water. Storgard in Finland.

555. DERMATINE, $(\dot{M}g, \dot{F}e)\ddot{S}i + 2\dot{H}$.

Reniform; stalactitic; fracture conchoidal; brittle. H. = 2·5; G. = 2·1. Resinous. Blackish green; streak yellow. Does not adhere to tongue. C.c.: silica 38, magnesia 22, protoxide of iron 12, water 23. Waldheim in Saxony.

556. CHLOROPHÆITE, $\dot{R}\ddot{S}i + \ddot{R}_2\ddot{S}i_3 + 4\dot{H}$.

Massive, rarely reniform. Coating or filling up geodes in amygdaloidal cavities. H. = 1·5; G. = 2·02 to 2·3. Sectile; fracture conchoidal. On first exposure transparent and olive-green to orange-yellow, but soon changes to black and opaque, splitting in so doing. Vitreous to shining. B.B. melts to a black glass. C.c.: silica 36·2, alumina 8·9, peroxide of iron 13·8, protoxide of iron 2·4, lime 3·8, magnesia 10, water 21·8. Rum and Canna in the Hebrides, Giant's Causeway. The original mineral from Rum has 22·8 iron peroxide and no alumina.

557. FORCHHAMMERITE, $\dot{F}e\ddot{S}i + 6\dot{H}$.

Granular massive. Subresinous to dull. Dark green. H. = 2; G. = 1·8. C.c.: silica 32·8, protoxide of iron 21·6, magnesia 3·4, water 42·2. Faroes.

558. KIRWANITE.

Fills druses in amygdaloids with divergent sheaf-like crystals. H. = 2; G. = 2·9. Opaque. Olive-green to dark green. C.c.: silica 40·5, alumina 11·1, protoxide of iron 23·9, lime 19·8, water 4·4. Loch Baa in Mull; Mourne Mountains in Ireland.

559. GLAUCONITE.

Round grains. Dull resinous. Light green. C.c.: silicate of protoxide of iron and potash. Ashgrove near Elgin; greensand of England, France, Germany, and America.

560. CELADONITE, $3\dot{R}\ddot{S}i_2 + \ddot{R}_2\ddot{S}i_3 + 5\dot{H}$.

Massive, forming crusts, as of agates. Earthy, sectile. H. = 1 to 2; G. = 2·6 to 2·8. Opaque, shining. Bright green. Feels greasy. C.c.: silica 54, alumina 3·8, ferric oxide 11·9, ferrous oxide 5·4, magnesia 6·8, potash 7·9, water 10. Orkney, Rum, and Fifeshire in Scotland. Giant's Causeway, Verona, Faroes, Iceland, Cyprus, Bohemia.

561. STILPNOMELANE, $2(\dot{F}e, \dot{M}g)\ddot{S}i + \ddot{A}l\ddot{S}i + 2\dot{H}$.

Massive or radiating-foliated. One cl. perfect; brittle. H. = 3 to 4; G. = 3 to 3·4. Opaque; vitreous to pearly. Greenish black. C.c.: 45·3 silica, 6·9 alumina, 38·3 iron protoxide (with 2 to 3 magnesia), and 9·5 water. Zuckmantel in Silesia and Weilburg in Nassau.

562. CHAMOISITE.

Oolitic and massive. H. = 3; G. = 3 to 3·4. Greenish grey to black; streak paler. C.c.: silica 14·3, alumina 7·8, protoxide of iron 60·5, water 17·4. Chamoison (or Chamoson) in Valais, the Vosges. *Berthierine* has 75 protoxide of iron and 5 of water; Moselle.

AUGITE AND HORNBLENDE GROUP.[1]

Hornblende and augite rather represent groups of mineral substances than single species. They are best distinguished when imperfectly formed, by the cleavage and angles of the prisms.

563. ENSTATITE (*Chladnite*), $\dot{M}g\ddot{S}i$.

Right prismatic. ∞P 92° to 93°; crystals ∞P̄∞ (*a*), ∞P̆∞ (*b*), ∞P (*m*), ½P̆∞ (*k*), ⅔P̄∞ (*q*), ⅙P̆∞ (*ψ*), ⅔P (*τ*) (fig. 497). Usually imbedded, or indistinct granular masses. Cl. macrodiagonal very perfect, prismatic ∞P distinct, brachydiagonal imperfect. H. = 5·5; G. = 3·1 to 3·3. Translucent throughout, or only on the edges; vitreous or pearly on the more perfect cleavage-planes. Colourless, greyish or greenish white, yellowish, or brown. Not affected by acids. B.B. almost infusible.

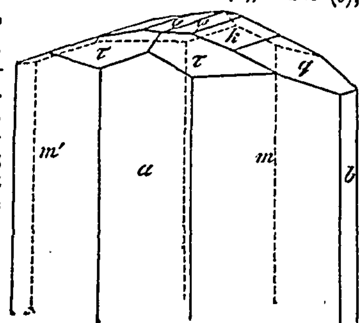


Fig. 497.

C.c.: 60 silica and 40 magnesia, but with 6 to 8 iron protoxide, 1 to 2 alumina, and 1 or 2 water. In olivine and serpentine rocks in Moravia, the Harz (Baste), and the Pyrenees.

564. BRONZITE (*Schiller Spar, Bastite*), $(\dot{M}g, \dot{F}e)\ddot{S}i$.

Right prismatic. ∞P 94°; only granular and foliated. Cl. brachydiagonal perfect, prismatic less so; fracture uneven, splintery. H. = 4 to 5; G. = 3 to 3·5. Translucent on thin edges; metallic pearly. Green, inclining to yellow or brown. Imperfectly sol. in h. acid, wholly in s. acid. B.B. becomes magnetic, and fuses in very thin splinters. C.c.: 43 silica, 26 magnesia, 2·7 lime, 7·4 iron protoxide, 3·3 iron peroxide, 2·4 chrome oxide, 1·7 alumina, and 12·4 water. *Bastite* is possibly altered enstatite. Belhelvie and Black Dog in Aberdeenshire, Baste, Tyrol, Baireuth, Styria.

565. PAULITE (*Hypersthene*), $(\dot{F}e, \dot{M}g)\ddot{S}i$.

Right prismatic. ∞P (*m*) 93° 30′, P̆2 (*c*), 2P̆2 (*i*), ⅔P̆⅔ (*u*), ∞P̆2 (*n*), ¼P̆∞ (*h*), ∞P̄∞ (*a*), ∞P̆∞ (*b*), ½P̆∞ (*k*), 2P̄∞ (*d*). Granular or disseminated. Cl. brachydiagonal very perfect, prismatic ∞P distinct, macrodiagonal very imperfect. H. = 6; G. = 3·3 to 3·4. Opaque or translucent on thin edges; vitreous or resinous, but metallic pearly on the cleavage planes, of which one is copper-coloured to violet or silvery. Pitch-black and greyish black; streak greenish grey or pinchbeck-brown, inclining to copper-red. Not affected by acids. B.B. melts more or

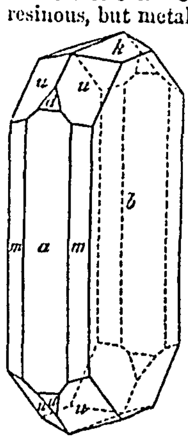


Fig. 498.

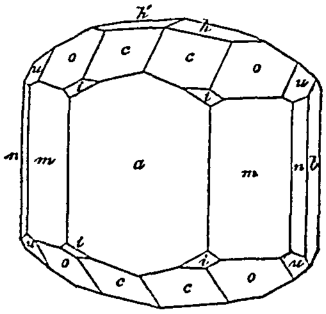


Fig. 499.

less easily to a greenish black glass, often magnetic. C.c.: generally 46 to 58 silica, 0 to 4 alumina, 11 to 26 magnesia, 1 to 5 lime, 13 to 34 iron protoxide, 0 to 6 manganese protoxide. Portsoy and Craig Buroch in Banffshire, Barra Hill in Aberdeenshire, Paul's Island, Labrador, and Greenland. Crystals occur in sanadine bombs at Lake Laach (*Amblystegite*), and in meteorites of Breitenbach. Hypersthene rock in Norway, Elfdal in Sweden, Cornwall (?), the Harz, and Canada. Chemically enstatite and paulite pass into one another; the essential difference is that the axial dispersion is uniformly $\rho < \nu$ in the former, and the opposite in the latter.

566. WOLLASTONITE (*Tabular Spar*), $\dot{C}a\ddot{S}i$.

Oblique prismatic, C 84° 30′. ∞P 87° 18′, 0P (*u* or *h′*), ∞P̄∞ (*c* or *p*), ∞P⅔ (*z*) 110° 7′, ∞P°2 (*x* or *e′*) 51°, −P̄∞ (*v*) 44° 27′, ½P̄∞ (*a*) 69° 56′ (fig. 500). Rarely crystallized, mostly broad prismatic or laminar. Frequently fibrous. Cl. along 0P and ∞P°∞ perfect, but planes uneven or rough; meet at 95° 23′. H. = 4·5 to 5; G. = 2·8 to 2·9. Translucent; vitreous or pearly on cleavage. White, inclining to grey, yellow, red, or brown; streak white.

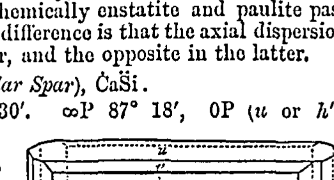


Fig. 500.

[1] Hornblende and augite agree so closely in crystalline forms and chemical composition that it has sometimes been proposed to unite them in one species. They, however, differ too widely to justify their union. Hornblende is more fusible, and ranges lower in specific gravity (hornblende from 2·931 to 3·415, augite 3·195 to 3·525). Though both possess a cleavage parallel to their vertical prisms, yet these differ in angular dimensions:—hornblende 124° 12′, augite 87° 6′. They also occur in distinct geognostic positions:—hornblende in rocks containing quartz or free silica, and mostly with minerals that are neutral compounds of silica, as orthoclase and albite; augite in rocks that do not contain free silica, and mostly with minerals that are not neutral silicates, as labradorite, olivine, and leucite. Hence there are two distinct series of massive or igneous rocks:—the hornblende series, including granite, syenite, diorite, diorite-porphyry, and red porphyry; and the augite series or hypersthene rock, gabbro, dolerite, nepheline rock, augite-porphyry, and leucite-porphyry.

Phosphoresces with heat or friction; gelatinizes in h. acid. B.B. difficultly fusible to a semitransparent glass. C.c.: 51·7 silica and 48·3 lime, but with 0 to 2 magnesia and 0 to 2 iron protoxide. Glen Gairn, Crathie, &c., in Aberdeenshire, Urquhart in Inverness, Skye, Banat, Finland, Sweden, Vesuvius (fig. 501), North America, Ceylon, Capo di Bove.

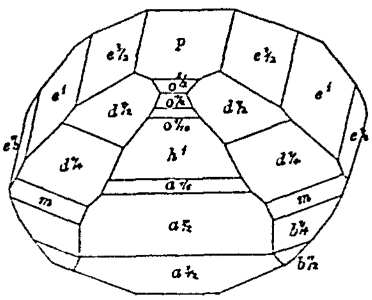


Fig. 501 (sp. 566).

567. Augite (*Pyroxene*), $\dot{R}\dddot{Si}=(\dot{C}a, \dot{M}g, \dot{F}e)\dddot{Si}$.

Oblique prismatic, C 74°11′. ∞P 87° 6′; P (*s* : *s*) 120° 48′; − P (*u*) 131° 30′; 2P (*o*) 95° 48′; 0P; 3P; ∞P°∞. In fig. 130 ∞P (*M*), ∞P°∞ (*r*), ∞P^c∞ (*l*), P(*s*); also various twins and hemitropes of same form (figs. 191, 502, 503). Almost always prismatic, imbedded, or attached; also granular, columnar, and scaly. Cl. prismatic along ∞P (with

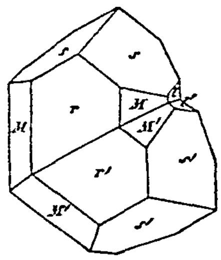


Fig. 502.

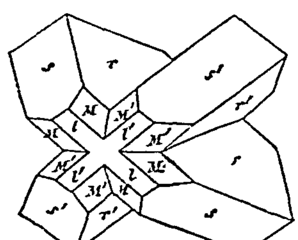


Fig. 503.

angles of 87° 6′ and 92° 54′), generally rather imperfect; orthodiagonal and clinodiagonal imperfect. H. = 5 to 6; G. = 3 to 3·5. Pellucid in all degrees; vitreous; in some pearly on ∞P°∞. Colourless, and white, but usually grey, green, or black. B.B. generally fusible; imperfectly soluble in acids. C.c. generally as follows:—

	Silica.	Lime.	Magnesia.	Iron.
(*a*) Magnesia augite	56·22	25·54	18·24	...
(*b*) Magnesia-iron augite	52·72	23·81	8·50	14·97
(*c*) Iron augite	49·06	22·29	...	28·65

Analysis gives 47 to 56 silica, 20 to 25 lime, 5 to 15 magnesia, 1 to 20 iron protoxide, with 0 to 3 manganese protoxide and 0 to 8 alumina. The alumina, chiefly found in very dark green or black augites, may in some replace either silica or part of the silicate.

The more important varieties are—

Diopside.—Greyish or greenish white, to pearl-grey or leek-green; streak white. Crystallized or broad columnar, or concentric lamellar. Transparent to translucent on the edges. Not affected by acids. B.B. fuses to a whitish semitransparent glass. C.c.: generally lime 26 and magnesia 18·5, with 55·5 silica. Mussa Alp (*Mussite*) and Ala (*Alalite*) in Piedmont, Schwarzenstein in Tyrol, Scandinavia, Finland, Urals, and North America.

Malacolite, Sahlite.—White, green, rarely yellow, brown, or red; streak white. Translucent, or only on the edges; vitreous, inclining to pearly. Seldom crystallized, mostly columnar

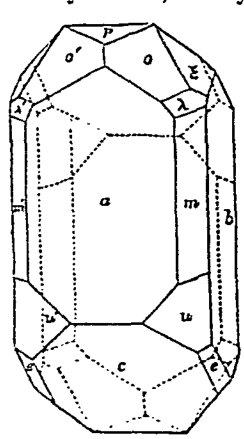


Fig. 504.

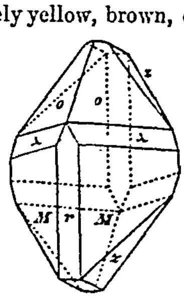


Fig. 505.

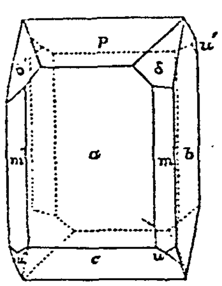


Fig. 506.

or lamellar. B.B. melts to a dark-coloured glass. Malacolite common in primary limestones in Scotland, as at Shinness, Ledbeg (fig. 505), and Glen Tilt. Fassa Valley (*Fassaite*), Piedmont, Arendal, Philipstadt in Sweden; Lake Baikal (*Baikalite*); near Lake Lherz in the Pyrenees (*Lherzolite*); Sala (or Sahla) in Sweden (*Sahlite*); Shinness (figs. 504, 506), Glenelg, Tiree, in Scotland; Tyrol; North America. *Coccolite* is a granular sahlite or augite.

Augite.—Leek-green, greenish black, or velvet-black, rarely brown; streak greenish grey. Vitreous to resinous; translucent or opaque. Only slightly affected by acids. B.B. fuses to a black, often magnetic glass. An essential component of many rocks, as basalt, dolerite, clinkstone, and augite porphyry; Germany, Auvergne, Vesuvius; St Kilda, Rum, Tiree, Dalnain, and Urquhart in Scotland. Augite crystals in basalt often contain very many microscopic crystals and glasses; also pores with fluid carbonic acid.

Hudsonite.—Cleavable lamellar, and jet-black, with green streak and bronzy tarnish, from the Hudson river; the most highly ferruginous variety.

Amianthus.—Some asbestiform minerals are augite, but the greater number hornblende.

Breislackite.—Fine yellowish or brown woolly crystals. Vesuvius, and Capo di Bove near Rome.

568. Diallage, $(\dot{C}a, \dot{M}g, \dot{F}e)\dddot{Si}$.

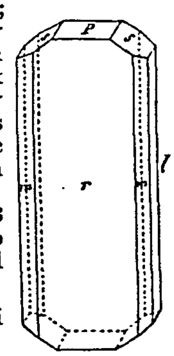
Like augite, and only a variety with very perfect cleavage in the clinodiagonal, which forms with a second cleavage an angle of 87°. Lustre metallic pearly; colour grey or pinchbeck-brown. H. = 4; G. = 3·23. B.B. melts easily to a greyish or greenish enamel. C.c.: 50 to 53 silica, 1 to 5 alumina, 15 to 23 magnesia, 11 to 20 lime, and 5 to 20 manganese protoxide. Constituent of the augite rock of the Cuchullins in Skye and of the gabbro of Unst and Ayrshire. Baste in the Harz, Silesia, the Alps, Apennines, and Urals. *Vanadine-Bronzite*, containing soda and vanadic acid, is similar. At Craig Buroch (Banffshire) diallage passes in paulite.

569. Jeffersonite.

Oblique prismatic. Cl. prismatic ∞P 87° 30′, and orthodiagonal. H. = 4·5; G. = 3·3 to 3·5. Dark olive-green, brown to black. Lustre greasy. A manganese and zinc augite, with 10·2 protoxide of manganese, and 10·15 oxide of zinc. Sparta in New Jersey.

570. Acmite, $2\ddot{F}e\dddot{Si}_3+3\dot{R}\dddot{Si}$.

Oblique prismatic. Crystals long often acute-pointed prisms. ∞P 87° 15′, ∞P̄∞ (*r*), P(*s*), 6P (*o*), − 6P^{c}3(*z*) (figs. 507, 508). Cl. like augite. H. = 6 to 6·5; G. = 3·4 to 3·6. Nearly opaque; vitreous. Brownish or greenish black; streak greenish grey. Imperfectly soluble in acids. B.B. fuses easily to a black magnetic glass. C.c.: 52 silica, 30 iron peroxide, 5 iron protoxide, and 13 soda, but with 1 to 3 manganese peroxide, and also 3 to 4 titanic acid. Eger and Porsgrund in Norway.



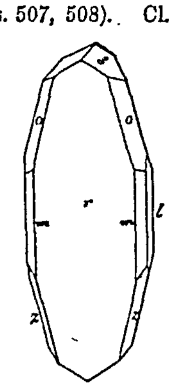


Fig. 507. (Sp. 570.) Fig. 508.

571. Ægerine, $\dot{R}_2\dddot{Si}_5+\ddot{R}\dddot{Si}+2\dot{N}a\dddot{Si}$.

Oblique prismatic; striated or reed-like prisms of 86° 30′ to 87° 45′. Cl. orthodiagonal perfect, less distinct clinodiagonal, and prismatic. H. = 5·5 to 6; G. = 3·4 to 3·5 or 3·6. Vitreous; translucent on edges, or opaque. Greenish black. B.B. fuses easily, colouring the flame yellow. Scarcely affected by acids. C.c.: 49 silica, 31·7 iron peroxide, 6·6 iron (and manganese) protoxide, and 12·7 soda, with a little magnesia and potash. Has the same relation to augite as arfvedsonite to hornblende. Near Brevig and Barkevig in Norway.

572. Spodumene, $4\ddot{Al}\dddot{Si}_3+3(\dot{L}i, \dot{N}a, \dot{K})\dddot{Si}$.

Oblique prismatic, C 69° 40′. ∞P 87° (fig. 509). Cl. prismatic ∞P and orthodiagonal, perfect; chiefly massive or foliated. H. = 6·5 to 7; G. = 3·1 to 3·2. Translucent; vitreous or pearly. Pale greenish grey or white to apple-green; streak white. B.B. intumesces slightly, tinging the flame momentarily purplish red, and fuses easily to a colourless glass. Not affected by acids. C.c.: 65 silica, 28·7 alumina, and 6·3 lithia. Killiney near Dublin, Utö in Sweden, Tyrol. *Killinite* (sp. 651), from Killiney, seems to be decomposed spodumene.

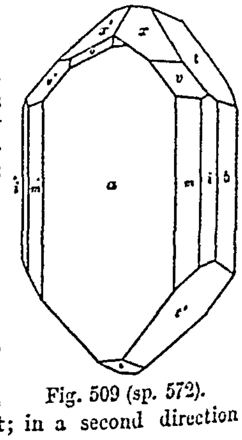


Fig. 509 (sp. 572).

573. Petalite (*Castor*), $4\ddot{Al}\dddot{Si}_6+3(\dot{L}i, \dot{N}a)\dddot{Si}_2$.

Oblique prismatic. Castor has C 67° 34′ and ∞P 86° 20′, in irregular rectangular prisms, petalite being massive and coarse granular. Cl. basal, distinct; in a second direction

(meeting at 141½°) less so. H. = 6·5 ; G. = 2·4 to 2·5. Greenish, greyish, or reddish white to pale red. Translucent; vitreous or pearly. B.B. melts easily into a porous obscure glass, colouring the flame red. Not affected by acids. C.c.: 78·3 silica, 17·4 alumina, 3·2 lithia, and 1·1 soda. Utö, Bolton in Massachusetts, York in Canada. *Castor* in Elba. *Milarite*, valley of Milar, Switzerland.

574. RHODONITE (*Manganese-Spar*), $\dot{M}n\ddot{S}i$.

Anorthic. $\infty\breve{P}\infty\,(a)$; $\infty\bar{P}\infty\,(b)$; $0P\,(c)$; $\infty P'\,(u)$; $\breve{P}'\infty\,(k)$; $\bar{P}\infty\,(s)$; $'\bar{P}'\infty\,(o)$; $m'\bar{P}'\infty\,(t)$: $a:b$ 111° 9′ ; $c:a$ 93° 28′ ; $n:a$ 106° 19′; but chiefly massive or granular. Cl. $\infty P\infty$ and $0P$, meeting at 87° 38′, perfect; brittle. H. = 5 to 5·5; G. = 3·5 to 3·7. Translucent; vitreous or partly pearly. Dark rose-red, bluish red, or reddish brown. Not affected by acids. B.B. fusible. C.c.: 45·8 silica and 54·2 manganese protoxide, with 3 to 5 lime and 0 to 6 iron protoxide. St Marcel, Långban, Ekaterinburg, the Harz, and New Jersey. *Bustamite*, pale greenish or reddish grey, with 14 lime, Mexico; *Fowlerite*, New Jersey, with 7 to 11 iron protoxide; and *Paisbergite*, Sweden, are varieties. *Hydropite*, *Photicite*, *Allagite*, and *Horn-Manganese* are mere mixtures.

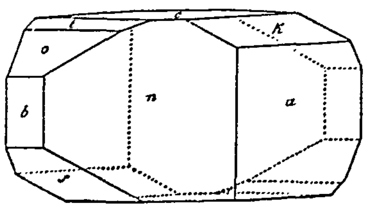


Fig. 510.

575. BABINGTONITE, $9(\dot{C}a, \dot{F}e, \dot{M}n)\ddot{S}i + \ddot{F}e\ddot{S}i_3$.

Anorthic. Crystals very low eight-sided prisms, small, attached. $g:h$ 90° 24′; $c:a$ 87° 27′; $a:b$ 112° 12′; $b:d$ 81° 8′; $c:d$ 150° 10′ (fig. 511). Cl. basal (c), very perfect; also along b. H. = 5·5 to 6; G. = 3·3 to 3·4. Thin laminæ translucent. Splendent vitreous; black. Not affected by acids. B.B. fuses easily with effervescence to a black magnetic bead. C.c.: 50·7 silica, 11 iron peroxide, 10·3 iron protoxide, 7·7 manganese protoxide, and 20·3 lime, in the Arendal specimens; one from Nassau gave about 17 of peroxide, with protoxides only 11. Tongue (Sutherland), Portsoy (Banffshire), Arendal, Nassau, and Gouverneur (New York).

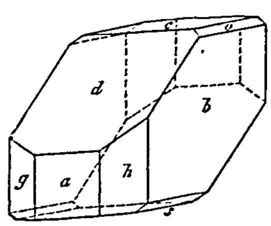


Fig. 511.

576. SZABOITE, $11\ddot{F}e\ddot{S}i_3 + 2\dot{C}a\ddot{S}i$.

Anorthic. $\infty P'\,(l)$; $\infty'P\,(m)$ 88° 40′; $\infty\breve{P}\infty\,(b)$; $\infty\bar{P}\infty\,(a)$; $P'\,(p)$; $'P\,(o)$; $2'\breve{P},\infty\,(y)$; $2\breve{P}'\infty\,(x)$ (fig. 512). H. = 6·5; G. = 3·5. Brownish red to reddish yellow. Pleochroic. C.c.: silica 52·4, peroxide of iron 44·7, lime 3·1. Slightly sol. in s. acid, more so in h. acid. Calvario on Etna, Mont Dore.

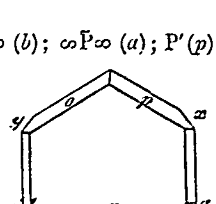


Fig. 512 (sp. 576).

577. ANTHOPHYLLITE, $3\dot{M}g\ddot{S}i + \dot{F}e\ddot{S}i$.

Right prismatic. ∞P 124° 30′. Cl. macrodiagonal, perfect. Clove-brown to purplish brown and leek-green. Translucent; radiating and foliated. Pearly on cl. plane. H. = 5·5; G. = 3·2. C.c.: silica 55·9, protoxide of iron 16·7, magnesia 27·8. B.B. very difficultly fusible. Hillswick, Shetland; Kongsberg and Modum, Norway; Greenland, and the United States.

578. HORNBLENDE.

Oblique prismatic (figs. 513 to 517; see also fig. 192). Distinct cleavage in several directions. H. = 4 to 6, but generally 5 (will scratch with knife); G. = 2·5 to 4·0, but mostly high. Mostly coloured. Lustre vitreous, in some silky or metallic pearly. Sol., but not very readily, in acids; more or less easily fusible. C.c.: anhydrous silicates and aluminates of lime, magnesia, iron protoxide; more sparingly of soda, yttria, and manganese protoxide. The chief species form by their decomposition highly fertile soils.

Amphibole.—Oblique prismatic, C 75° 10′. ∞P 124° 30′, P 148° 30′. The crystals short and thick, or long and thin prismatic; formed especially by $\infty P\,(m)$, $\infty P^c\infty\,(x)$, and bounded on the ends chiefly by $0P\,(p)$ and $P\,(r)$. Twins common, with the chief axis the twin axis. Very often radiated, fibrous, or columnar, or granular. Cl. prismatic along ∞P 124½°, very perfect; orthodiagonal and clinodiagonal very imperfect. H. = 5 to 6; G. = 2·9 to 3·4. Pellucid in all degrees; vitreous, but sometimes pearly or silky. Colourless or white, but usually some shade of grey, yellow, green, brown, or black. B.B. fuses, generally intumescing and boiling, to a grey, green, or black glass. Those containing most iron are most fusible, and are also partially sol. in h. acid, which scarcely affects the others. C.c. very variable; the silica is partly replaced by alumina, specially in the green or black varieties; RO is chiefly MgO, CaO, and FeO. Lime is the most

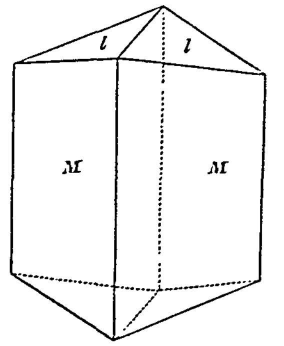


Fig. 513.

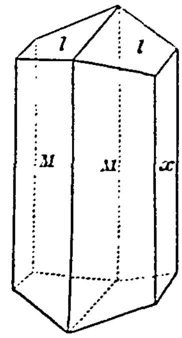


Fig. 514.

constant element, in most from 10 to 12; magnesia and iron protoxide replace each other, the one increasing as the other diminishes. With $4\ddot{S}i$ and $\dot{R} = 2\dot{M}g + 1\dot{C}a + 1\dot{F}e$, the average composition is 53·6 silica, 17·8 magnesia, 12·5 lime, and 16·1 iron protoxide; but

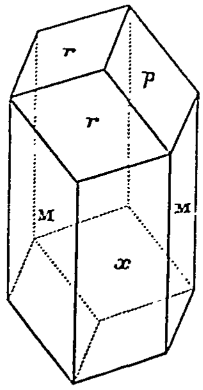


Fig. 515.

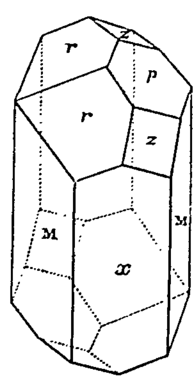


Fig. 516.

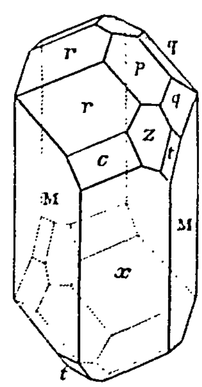


Fig. 517.

analyses give 40 to 60 silica, 0 to 17 alumina, 0 to 30 magnesia, 10 to 15 lime, 0 to 36 iron protoxide (or peroxide), and 0 to 4 manganese protoxide, 0 to 8 soda, 0 to 3 potash, and 0 to 1·5 fluorine with a little water.

The more important varieties are—

Amianthus, *Asbestos*, and *Byssolite*, $2\dot{M}g\ddot{S}i + \dot{C}a\ddot{S}i$. Fine fibrous. White, grey, or green. The fibres often easily separable, elastic, and flexible. Unst, Shinness, Portsoy, Savoy, Tyrol, Corsica.

Tremolite, *Grammatite*, $3\dot{M}g\ddot{S}i + \dot{C}a\ddot{S}i$, with 58·35 silica, 28·39 magnesia, and 13·26 lime. White, grey, green; in long prismatic crystals, often striated longitudinally. Pearly or silky; semi-transparent or translucent. B.B. fuses readily to a white or nearly colourless glass. Loch Shin (Sutherland), Glen Tilt, Glenelg, Tiree, Cornwall, Cumberland, Sweden, the Alps, Pyrenees, Silesia, Siberia, North America.

Nephrite, or *Jade*, is a tough, compact, fine-grained tremolite, with H. = 6 to 6·5; G. = 2·9 to 3·1. Fracture close splintery. Very tenacious. Translucent; dull to resinous. Leek-green to blackish green. Feels slightly greasy. Formerly made into ring-stones, amulets, idols, and war axes. New Zealand, China, Mexico, Peru, Balta (Shetland).

Actinolite, *Actinote*, or *Strahlstein* $(\dot{C}a, \dot{M}g, \dot{F}e)\ddot{S}i$. Colour green, inclining to black, grey, or brown. Translucent throughout, or only on the edges. Long prismatic crystals, or radiated-columnar masses. B.B. melts to a greenish or blackish enamel. Fethaland and Colafirth and Hillswick (Shetland), Oronsay, Ord Ban (Inverness), Sweden, Tyrol, North America.

Hornblende.—$6\dot{R}\ddot{S}i + \ddot{R}_2\ddot{S}i_3$. Green or black, seldomer brown or grey. G. = 3·1 to 3·3. B.B. fuses rather easily to a yellow, greenish, or black enamel. Three varieties are distinguished. (a) The noble or *Pargasite*, pale celadon- or olive-green, and strong pearly or vitreous lustre; at Pargas in Finland, Tyrie in Scotland. (b) Common hornblende, dark leek- or blackish-green, opaque; streak greenish grey. A constituent of many rocks, as in Norway, the Alps, and Scottish Highlands (Ballater, Ben Arihaar, Glenbucket, Colafirth). (c) Basaltic, foliated, with bright even cleavage, opaque, velvet-black; streak grey or brown. Generally contains alumina (9 to 15) and much (5 to 11) iron peroxide. In basalt and volcanic rocks. Etna, Vesuvius, Rhineland, Bohemia.

579. Arfvedsonite, $\dot{R}\ddot{S}i+\dot{F}e\ddot{S}i_3$.

Oblique prismatic. ∞P; $\infty P^6\infty$; P; $2P^6\infty$ 120° 24′; 0P. Cl. ∞P 124° 22′, perfect; also 0P. Massive. Black; opaque. Vitreous. H. = 6; G. = 3·44. C.c.: silica 43, alumina 4·5, peroxide of iron 3·8, protoxide 34, lime 5·7, soda 8·5. Streak dark blue-grey. Fusible in fine splinters in the flame of a candle. B.B. intumesces and melts easily to a black magnetic globule. Not sol. in acids. Kangerdluarsuk in Greenland, Frederiksvärn, Arendal, El Paso in Colorado.

580. Pilolite, $4\dot{M}g\ddot{S}i_2+\ddot{\ddot{A}}l\ddot{S}i_2+15\dot{H}$.

Felted or matted fibres more or less dense. Cream yellow to buff. Dull; extremely tough; absorbs water like a sponge. H. = 1 to 2·5; G. = ·63 to 1·34. Structure varies considerably, and has given rise to trivial names, as mountain paper, mountain leather, mountain flesh, rock cork, &c. *Mountain Paper* occurs in thin sheets at Boyne Castle near Banff; *Mountain Leather*, Burn of the Cairn (Cabrach), Tod Head (Kincardineshire), Leadhills, Strontian; *Rock Cork*, Portsoy and Boyne Castle, Saxony, and Sweden. C.c.: silica 51·6, alumina 8·6, ferrous oxide 2·88, magnesia 10·2, water 23·3.

581. Krokidolite, $3\dot{F}e\ddot{S}i+(\dot{N}a,\dot{M}g)\ddot{S}i_2+2\dot{H}$.

Delicate, easily separable, but tough fibres; elastic. H. = 4; G. = 3·2 to 3·3. Translucent; silky. Indigo-blue; streak lavender. B.B. fuses easily to a black magnetic glass. C.c.: silica 50·3, iron protoxide 35, magnesia 2·2, soda 6·7, water 5·8. Stavern in Norway, Greenland. A fibrous yellow mineral from Orange river, South Africa, has been referred here; its fibres are not separable, and its hardness is 7. *Abriachanite*, a very similar mineral, of blue colour, occurs near Inverness.

582. Glaucophane, $9\dot{R}\ddot{S}i+2\ddot{\ddot{A}}l\ddot{S}i_3$.

Oblique prismatic. Cl. prismatic, perfect; fracture conchoidal. H. = 5·5; G. = 3·1. Translucent; vitreous to pearly. Indigo-blue, grey, bluish black. B.B. becomes brown, fusing easily to olive-green glass. C.c.: silica 56·5, alumina 12·2, protoxide of iron 10·9, magnesia 8, soda 9·3. Island of Syra.

583. Hermannite, $\dot{M}n\ddot{S}i$.

Granular and arborescent. Rose-red. G. = 3·4. C.c.: protoxide of manganese 46·7, silica 48·9, lime 2, magnesia 2·4. Cummington in Massachusetts.

584. Grunerite, $\dot{F}e\ddot{S}i$.

Asbestiform. G. = 3·7. Brown; silky lustre. C.c.: protoxide of iron 51·55, silica 45·45. Mt. des Maures (Var).

585. Iolite (*Cordierite, Dichroite*), $\ddot{\ddot{A}}l\ddot{S}i_3+2(\dot{M}g,\dot{F}e)\ddot{S}i$.

Right prismatic. ∞P (*P*) 119° 10′, middle edge of P 95° 36′. Form ∞P (*T*), $\infty \breve{P}\infty$ (*l*), 0P (*m*); and this with $\infty \bar{P}\infty$ (*k*), $\infty \breve{P}3$ (*d*), $\breve{P}\infty$ (*n*), and $\frac{1}{2}P$ (*s*), (fig. 518); short, prismatic. Cl. $\infty \bar{P}\infty$ distinct, traces along $\breve{P}\infty$; fracture conchoidal or uneven. H. = 7 to 7·5; G. = 2·5 to 2·7. Transparent or translucent; vitreous, inclining to resinous. Colourless, but chiefly dark blue, or violet, green, brown, yellow, and grey. Often with distinct trichroism; on 0P blue, on $\infty \breve{P}\infty$ grey, and on $\infty \bar{P}\infty$ yellowish. B.B. fuses difficultly to a clear glass; slightly affected by acids. C.c.: 48 to 51 silica, 29 to 33 alumina, 8 to 13 magnesia, 1 to 12 iron protoxide. Cabo de Gata in Spain, Bodenmais (*Peliom*), Orijerfvi in Finland (*Steinheilite*), Norway, Sweden, Greenland, North America, and Siberia. Small rolled masses of an intense blue colour and transparent, found in Ceylon, are the *Sapphire d'Eau* or *Luchssapphir* of the jewellers.

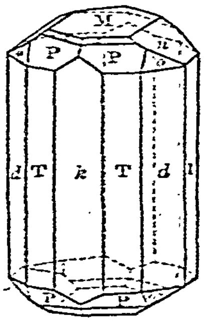


Fig. 518.

The following have been considered cordierite altered, or with 2 to 6 atoms water:—(*a*) *Bonsdorfite, Hydrous Iolite*, greenish brown or dark olive-green; near Åbo. (*b*) *Esmarkite, Chlorophyllite*, large prisms or foliated, green or brownish; near Cabrach (Aberdeen), Brevig in Norway, Unity in Maine, and Haddam in Connecticut. (*c*) *Fahlunite, Triclasite*, compact, greenish brown or black, foliated; H. = 2·5 to 3; G. = 2·5 to 2·8; Falun. (*d*) *Huronite*, granular; pearly, yellowish-green; H. = 3·3; G. = 2·86; infusible and insoluble; Lake Huron. (*e*) *Weissite*, kidney-shaped and ash-grey or brown; Falun and Lower Canada. (*f*) *Pyrargillite*, indistinct imbedded crystals, black passing into brown or red, dull resinous lustre; H. = 3·5; G. = 2·5; Helsingfors. (*g*) *Pinite*, crystallized, or massive and laminar, with imperfect cleavage; H. = 2 to 3; G. = 2·7 to 2·9, semitranslucent or opaque, dull or resinous, and dirty grey, green, or brown; B.B. fuses to a glass, sometimes clear, at other times dark-coloured; Auvergne, Schneeberg, Penig in Saxony, the Harz, Cornwall, Cabrach and Torry (Aberdeenshire), the United States, and Greenland (*Gieseckite*, sp. 650). *Oosite* from Geroldsau in Baden, snow-white, opaque, fragile, is similar. (*h*) *Gigantolite*; H. = 3·5; G. = 2·8 to 2·9; opaque, dull resinous, and greenish grey or brown; B.B. intumesces slightly, and fuses easily to a greenish slag; Tammela in Finland. (*i*) *Praseolite*, lamellar and green; Brevig in Norway.

586. Emerald (*Beryl*), $\ddot{\ddot{A}}l\ddot{S}i_3+3\dot{G}l\ddot{S}i$.

Hexagonal; P 59° 53′. Crystals of ∞P, 0P, and ∞P, $\infty P2$, 0P, P (*a, p, c, s*, fig. 519) are prismatic, generally with vertical striæ. Cl. basal, rather perfect; ∞P imperfect. H. = 7·5 to 8; G. = 2·6 to 2·8. Transparent or translucent; vitreous. Colourless or white, but generally green, sometimes very brilliant; also yellow and smalt-blue. B.B. melts with difficulty on the edges to an obscure vesicular glass. Not affected by acids. C.c.: 67·5 silica, 18·7 alumina, and 13·8 glucina, with 0·3 to 3 iron peroxide, and 0·3 to 3·5 chrome oxide in the rich green emerald. *Emerald*, bright green; G. = 2·710 to 2·759; occurs in Muso Valley near Bogota, also in Salzburg and the Urals. *Beryl*, or *Aquamarine*, colourless, or less brilliant; G. = 2·677 to 2·725; near Mursinsk and Nertchinsk in Siberia, Salzburg, and Brazil; in the United States, where at Grafton, between the Connecticut and Merrimack, crystals 4 to 6 feet long, and weighing 2000 to 3000 lb, occur; Mourne Mountains in Ireland; Mount Battock and Cairngorm in Scotland (fig. 98). *Common Beryl* at Falun in Sweden, Fossum in Norway, Limoges in France, Rabenstein in Bavaria, Nigg Bay and Pitfodels and Rubislaw near Aberdeen (*Davidsonite*), Struay Bridge (Ross). Emerald and beryl are much valued as precious stones. Known from quartz by face *p*. Forms shown in figs. 92, 95, 96, 97, 98, 276.

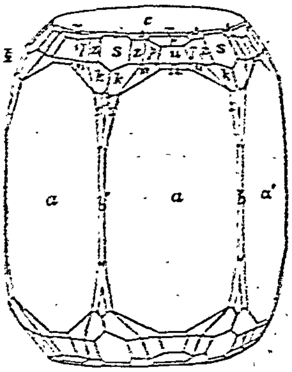


Fig. 519.

587. Leucophane, $6\dot{C}a\ddot{S}i+3\dot{G}l\ddot{S}i+2NaF$.

Right prismatic. ∞P 91°. Cl. basal perfect. H. = 3·5 to 4; G. = 2·97. Pellucid. Wine-yellow to olive-green. Vitreous. B.B. fuses to pale violet-blue bead. C.c.: silica 47, lime 23·4, glucina 10·7, soda 11·3, fluorine 6·6. Lamö in Norway.

588. Melinophane, $7(\dot{R}_3\ddot{S}i_2)+6NaF$.

Pyramidal. P 122° 23′. Mostly lamellar. H. = 5; G. = 3. Honey-yellow to citron-yellow. Brevig and Frederiksvärn.

Felspar Group.

Crystallization oblique prismatic or anorthic; very similar both in aspect and in angles. Cl. very distinct, especially the basal P; less so the clino- or brachydiagonal M. G. = 2·4 to 3·2, but mostly 2·5 to 2·8; H. = 6 or a little more. Slightly or not at all soluble in acids. B.B. fusible, but often with difficulty. Translucent; pure varieties transparent. Colourless, white, or shades of red; less commonly of green or yellow. C.c.: anhydrous silicates of alumina, and of an alkali or alkaline earth.

The felspars are very important constituents of the earth's crust, occurring in nearly all the igneous rocks, and in many of the stratified crystalline schists. In true strata they are found chiefly as fragments or decomposed, and in the latter state form a large part of wet soils and clays. By the older mineralogists and in popular language many species are conjoined under the common name of *felspar* which are now considered as distinct, each of them having not only its peculiar physical and chemical characters, but also geognostic position and associated groups of minerals. Thus orthoclase, and the other more siliceous felspars with potash, abound in granite and the plutonic rocks; the less siliceous, with soda and lime, characterize the volcanic rocks,—*e.g.*, labradorite the basaltic group, glassy felspar the trachytic. Orthoclase is associated with quartz, hornblende, and mica; glassy felspar either with hornblende and a black mica or with augite; labradorite with augite, very rarely with quartz or hornblende.

The felspars are best known from similar minerals by their hardness (they scarce scratch with a good knife), difficult fusibility, and unequal cleavages. The following marks may aid the student in distinguishing the more common species. In orthoclase the basal cleavage plane forms a right angle with the clinodiagonal cleavage planes *M* on both hands; in the triclinic or plagioclase felspars the angles are unequal. Orthoclase, albite, andesine, and oligoclase are insoluble in acids; labradorite and anorthite are more or less soluble. In granite, when decomposing, orthoclase often becomes reddish or dark-red; oligoclase dull green, and at length white.

Walterhausen considers that the felspars are mixtures of three true species, forming a series with the oxygen of the silica, alumina, and RO in the proportions $x:3:1$,—x ranging from 24 to 4. Tcher-

mak and most mineralogists now take a similar view, regarding orthoclase, albite, and anorthite alone as true species, of which the others are mixtures. Those consisting essentially of potash and soda only are mechanical mixtures of orthoclase and albite, the distinct lamellæ being visible by the microscope; those again that contain essentially lime and soda together are, sometimes at least, chemical, being isomorphous compounds of albite and anorthite in various proportions, and with corresponding transitions in crystallographic and physical properties. Notwithstanding this, these intermediates must be regarded as independent mineral species, inasmuch as they are severally typical of certain rocks, and have characteristic forms differing from each other in angular inclination.

589. ORTHOCLASE, $\dddot{Al}\ddot{Si}_3+\dot{K}\ddot{Si}_3$.

Oblique prismatic, C = 63° 57′. ∞P (T and l) 118° 47′; $P^{\circ}\infty$ (x) 65° 46′; $2P^{c}\infty$ (n) 90° 71′; $2P^{\circ}\infty$ (y) 35° 45′. The commonest and simplest forms are ∞P, $0P$, $P^{\circ}\infty$, and $\infty P^{c}\infty$ (M), ∞P, $0P$ (P), $2P^{\circ}\infty$ (figs. 520 to 527). When ∞P predominates the crystals

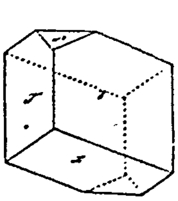


Fig. 520.

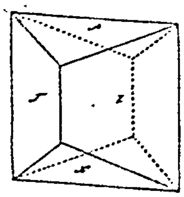


Fig. 521.

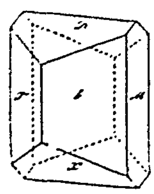


Fig. 522.

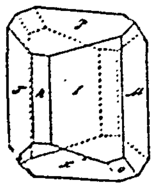


Fig. 523.

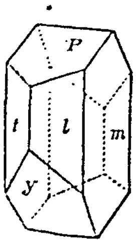


Fig. 524.

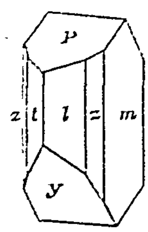


Fig. 525.

are short rhombic prisms; when $\infty P^{c}\infty$ predominates they are tabular; when ∞P and $\infty P^{c}\infty$ predominate they are short hexagonal prismatic, when $0P$ and $\infty P^{c}\infty$ they are rectangular prismatic, often much lengthened. Twins are very frequent, and occur according primarily to four laws. *First*, through revolution of one half or of a whole crystal, then forming interpenetrating twins round a vertical axis (fig. 195). In the case of this hemitropic revolution one of the external faces becomes a face of union. According as the right or the left half (or whole crystal) is conceived to be that which has been revolved the crystals are termed right and left, as in figs. 188, 189. *Second*, by revolution of one half around an axis normal to M; in such twins the composition is not evidenced externally except by sutures. *Third*,

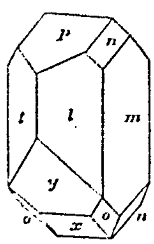


Fig. 526.

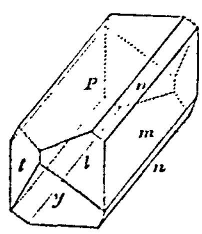


Fig. 527.

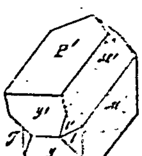


Fig. 528.

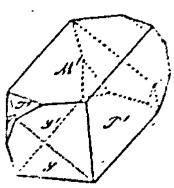


Fig. 529.

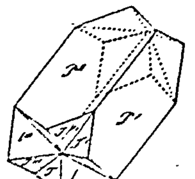


Fig. 530.

through revolution round an axis normal to P, forming orthorhombic prisms which show a herring-bone lineation, through the meeting of striæ commonly present upon the face M parallel to the intersection of its edge with the face T (fig. 528). *Fourth*, by revolution round an axis normal to $2P^{c}\infty$ (n); this also forms a prism the section of which is nearly square (fig. 529). Compound twins on this last type are formed of 3 to 4 and 8 crystals (fig. 530).

Occurs also massive, and coarse or fine granular. Cl. basal (P), very perfect; clinodiagonal (M), perfect (P : M = 90°); fracture conchoidal or splintery. H. = 6; G. = 2·53 to 2·58. Transparent to translucent on the edges; vitreous but pearly on cl.; and also opalescent, with bluish or changing colours. Occasionally colourless but generally red, yellow, grey, or green. B.B. fuses with difficulty to an opaque vesicular glass. Not affected by acids. C.c.: 64·6 silica, 18·5 alumina, and 16·9 potash, but generally 10 to 14 potash, 1 to 4 soda, 0 to 1·3 lime, 0 to 2 iron peroxide. Varieties are—

(1) *Adularia* and *Ice-spar*, transparent or translucent, splendent, and almost colourless. Some with bluish opalescence are named *Moonstone*; St Gotthard, Mont Blanc, Dauphiné, Arendal, Greenland, and Ceylon.

(2) *Common Felspar*, generally white or red, especially flesh-red, is a common constituent of many rocks. Crystals at Baveno on Lago Maggiore, Lomnitz in Silesia, Mourne Mountains and Wicklow in Ireland, Aberdeenshire (at Rubislaw 6 or 8 inches long) in Scotland, and at Carlsbad and Elnbogen in Bohemia. *Amazon Stone*, verdigris-green, from Sutherland, Lake Ilmen, and Colorado, and *Murchisonite*, golden or greyish yellow, from Arran and Dawlish, are varieties.

(3) The *Glassy Felspar* or *Sanidine* (C 64° 1′, ∞P 119° 16′) contains 3 to 12 potash and 3 to 10 soda. Crystals imbedded; vitreous, translucent, and often much cracked; Arran, Eigg, and other parts of Scotland, Drachenfels, Auvergne, and other countries.

Orthoclase occurs in granite, gneiss, and porphyry in many countries. It is commonly associated with quartz; sometimes, as in the *Graphic Granite* of Sutherland, Harris, and Portsoy, in letter-like combinations of the latter. It is very liable to decomposition, when it is converted especially into kaolin, used for manufacturing porcelain and stoneware. The adularia or moonstone and the green amazon stone are cut as ornamental stones. *Leelite*, from Biddean nam Bian in Argyllshire and Grythyttan in Sweden, is a somewhat siliceous horny-lustred flesh-coloured compact variety. *Petuntze* and *Hornstone* are similar but more impure. *Microcline* is a variety with angle distorted by interstitial penetration, by oligoclase (Sutherland), and by albite (Frederiksvärn, &c.).

590. ALBITE, $\dddot{Al}\ddot{Si}_3+\dot{Na}\ddot{Si}_3$.

Anorthic. $0P$ (P) : $\infty\breve{P}\infty$ (M) 86° 24′; $\infty P'$ (l) : $\infty'P$ (T) 122° 15′; but angles variable. Crystals, generally like those of orthoclase, are tabular or prismatic (fig. 197). Hemitropes common, especially united by a face of $\infty\breve{P}\infty$ (figs. 531, 532) the re-entering angle between the faces of $0P$ (P and P') 172° 48′ being very characteristic. Fig. 198 is another common hemitrope. Also massive, and in radiating plates. Cl. basal and brachydiagonal, almost equally perfect; fracture conchoidal or uneven. H. = 6 to 6·5; G. = 2·6 to 2·67. Rarely transparent; vitreous, pearly on the cl. Colourless, but generally white, grey, green, red, or yellow; streak white. B.B. difficultly fusible, tinging the flame yellow, to a white semiopaque glass. Not affected by acids. C.c.: 68·6 silica, 19·6 alumina with 0·1 to 1 iron peroxide, and 11·8 soda, with 0·3 to 4 lime, 0 to 2·5 potash. Hence albite and orthoclase both contain soda and potash, only in different proportions. Albite is most easily recognized by its frequent re-entering angles, its readier fusibility, and the obliquity (93° 36′) of its cl. planes, often marked with striæ. *Pericline* is a variety of which fig. 533 is a typical form.

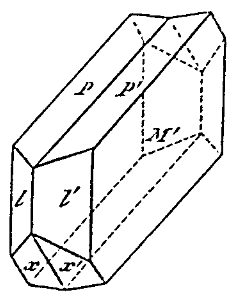


Fig. 531.

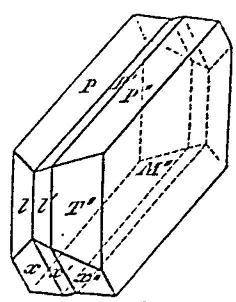


Fig. 532.

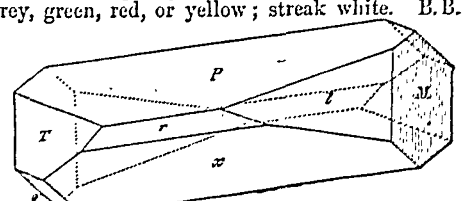


Fig. 533.

Albite is a constituent of many "greenstones," as at Corstorphine (Edinburgh), and of granite, syenite, gneiss, porphyry, and trachyte. Crystallized at Murdoch's Cairn, Aberdeenshire, being the colourless felspar of the red granites of Scotland. Dauphiné, St Gotthard, Tyrol, Salzburg, and Arendal.

Adinole is a compact variety similar in appearance to *Leelite*.

591. ANORTHITE, $\dddot{Al}\ddot{Si}+\dot{Ca}\ddot{Si}$.

Anorthic. $0P$ (P) : $\infty\breve{P}\infty$ (M) 85° 50′; $\infty P'$ (l) : $\infty'P$(T) 120° 30′. Hemitropes common on both M and P. Angle between P and P' 180° 24′. Cl. basal and brachydiagonal, perfect. H. = 6;

G. = 2·7 to 2·78. Transparent or translucent; vitreous. Colourless or white. B.B. fuses to a clear glass; soluble without gelatinizing in con. h. acid. C.c.: 43 silica, 36·9 alumina, 20·1 lime. sometimes

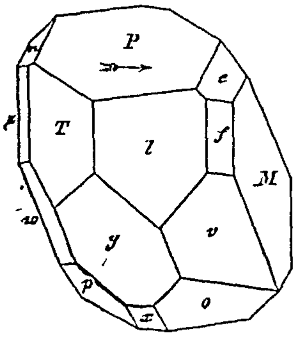


Fig. 534.

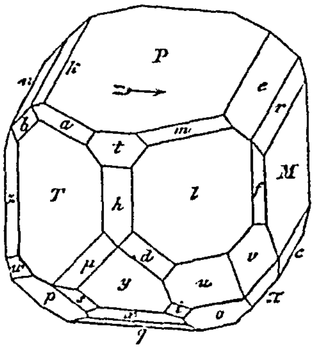


Fig. 535.

with magnesia and soda. Fetlar in Shetland; Lendalfoot in Ayrshire, in gabbro; Monte Somma, Iceland, Java. *Lepolite* and *Amphodelite* are varieties. In *Latrobite* the greater part of the lime is replaced by potash. Glen Gairn and Labrador. At both rose-red.

592. Oligoclase, $2\dddot{A}l\dddot{S}i_3+(\dot{N}a, \dot{C}a)_2\dddot{S}i_3$.

Anorthic. 0P : $\infty\breve{P}\infty$ 86° 10′; $\infty P'$: $\infty' P$ 120° 42′. Hemitropes face *m*, with *p* : *p′* 173° 4′; *l* : *l* 120° 20′; *y* : *y* 179° 9′; *x* : *x* 175° 59′. Cl. basal, perfect; brachydiagonal, less so. H. = 6; G. = 2·62 to 2·84. Vitreous, resinous on the cl. White, with a tinge of green, grey, or red. B.B. melts easier than orthoclase or albite to a clear glass; not affected by acids. C.c.: 63 silica, 23·4 alumina, 8·4 soda, and 4·2 lime; thus nearly = 3 albite and 1 anorthite. Distinguished from orthoclase by the marked striæ on the faces; less readily from albite, but more fusible and G. higher. The common associate of orthoclase in the Scotch grey granites, especially in vein granite, as at Rispond and Ben Loyal (figs. 536, 537) in Sutherland, and at

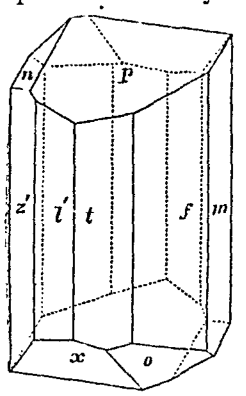


Fig. 536.

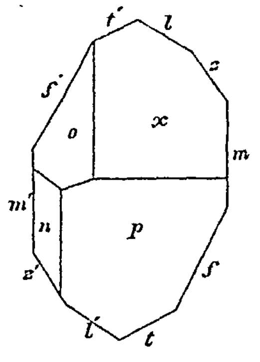


Fig. 537.

Rubislaw; Scandinavia, Urals, Harz, and North America. The *Sunstone*, from Foinaven in Sutherland, Norway, Lake Baikal, and Ceylon, with a play of colour due to imbedded crystals of rubinglimmer (göthite), belongs to this species.

593. Labradorite, $\dddot{A}l\dddot{S}i_3+(\dot{C}a, \dot{N}a)\dddot{S}i$.

Anorthic. 0P : $\infty\breve{P}\infty$ 86° 40′; 0P : $\infty' P$ 111°; 0P : $\infty P'$ 113° 34′; $\infty P'$: $\infty' P$ 121° 37′; $\infty\breve{P}\infty$: $\infty P'$ 120° 53′; $\infty\breve{P}\infty$: $\infty' P$ 117° 30′. Hemitropes of three types:—(1) according to the first law of orthoclase as in fig. 538; that is, vertical revolution and face of union $\infty\breve{P}\infty$; (2) revolution of one half with reunion on the face $\infty\breve{P}\infty$,

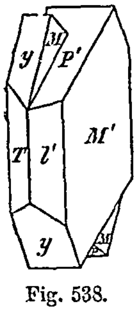


Fig. 538.

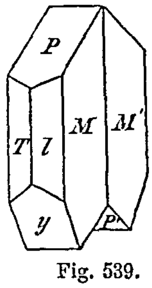


Fig. 539.

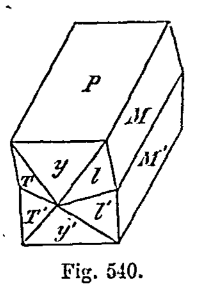


Fig. 540.

as in fig. 539; (3) with twin face P, as in fig. 540. Hemitropes of the last form also occur in which the lower half consists of a hemitrope formed according to the second method. Crystals imbedded in rocks consist generally of repeated twins affording an angle of 173° 20′. Cl. basal, perfect; brachydiagonal, less so; both usually striated on account of the above twinning. H. = 6; G. = 2·68 to 2·74. Translucent; vitreous, on the cl. resinous. Grey, passing into white, green, yellow, or red. The faces of $\infty\breve{P}\infty$ often exhibit very beautiful changing colours—blue, green, yellow, red, or brown—sometimes bands intersecting at certain angles. B.B. fuses more readily than orthoclase to a compact colourless glass. Sol. in h. acid. C.c.: 52·9 silica, 30·3 alumina, 12·3 lime, and 4·5 soda. It is thus = 1 albite and 3 anorthite. Common constituent of dolerite, gabbro, and hypersthene rocks. In Scotland, Labrador, Finland, Harz, Tyrol; also at Etna and Vesuvius.

594. Andesine, $\dddot{A}l\dddot{S}i_3+(\dot{N}a\dot{C}a)\dddot{S}i$.

Anorthic. Crystals similar to albite and anorthite. Twin face *M*. Crystals generally formed of repeated plates. G. = 2·67 to 2·7. Physical properties like albite; more easily fusible to a porous white glass; h. acid sometimes dissolves out alternate laminæ of crystals. C.c.: 59·7 silica, 25·6 alumina, 7·7 soda, and 7 lime, and thus nearly 1 of albite and 1 anorthite. Typical of the primary limestones and a granitic belt therein in Scotland, as at Shinness, Urquhart, Dalnain, &c. In the Andes, the Vosges, and Iceland.

595. Hyalophane, $\dddot{A}l\dddot{S}i_3$, $\dot{K}\dddot{S}i_3+\dddot{A}l\dddot{S}i$, $\dot{B}a\dddot{S}i$.

Oblique prismatic; resembles orthoclase; crystals and angles nearly the same. Cl. 0P, perfect. H. = 6 to 6·5; G. = 2·8 to 2·9. Transparent. Lustre vitreous. Colourless, white, and flesh-red. C.c.: silica 52·7, alumina 21, baryta 15·1, potash 7·8, soda 2·1. B.B. difficultly fusible to a blebby glass, not acted upon by acids. Binnen in Valais, Jacobsberg in Sweden.

596. Barsovite, $\dddot{A}l\dddot{S}i+\dot{C}a\dddot{S}i$.

Right prismatic, or oblique prismatic. H. = 5·5 to 6; G. = 2·58. Snow-white; translucent. Fracture granular. Pearly. C.c.: silica 42·2, alumina 36·4, lime 19·8. Gelatinizes in h. acid, difficultly fusible. A dimorphic form of anorthite. Barsovskoi in the Urals.

597. Saussurite.

A massive, granular, translucent, white or pale green felspathic mineral of the nature of anorthite mixed with labradorite. H. = 6 to 7; G. = 3·26 to 3·4. Probably a mixture. Occurs in loose blocks near Geneva, and in Corsica. In China and in India is carved under the name of Oriental jade (nephrite). Seems to be confounded also with zoizite, and perhaps with yu (prehnite). *Jadeite* is similar.

Zeolite Group.

These crystallize in all the systems except the anorthic, and themselves present great variety of development. Mostly hyaline and white; rarely red, grey, or yellow. Cl. generally distinct. All yield water in closed tube; all fusible B.B. most easily, and often intumescing; all sol. in acids, and mostly gelatinize or deposit silica. They are hydrated silicates of alkalies, or alkaline earths, mostly with silicates of alumina, but rarely contain magnesia. Some mineralogists regard the water as basic, in union with silica, and Kenngott gives the formula in that form, thus:—

Analcime, $(\dot{N}a\dddot{A}l)$ $2\dddot{S}i+2(\dot{H}, \dddot{S}i)$,

Natrolite, $(\dot{N}a\dddot{A}l)$ $2\dddot{S}i+2(\dot{H}, \dddot{S}i)$,

Stilbite, $\dot{C}a$, $\dddot{A}l+6(\dot{H}, \dddot{S}i)$,

and the others similar. They are generally found in amygdaloidal cavities or fissures of trap or plutonic rocks, apparently as deposits from water percolating into them, and are thus probably products of decomposing nepheline or felspars, or hydrated felspars themselves. They never form constituents of rocks. Natrolite, scolezite, thomsonite, and the connected varieties are marked by their needle-like radiating forms; stilbite and heulandite by their broad, foliated, pearly cleavage.

598. Pectolite, $4\dot{C}a\dddot{S}i+\dot{N}a\dddot{S}i_2+\dot{H}$.

Oblique prismatic, C 84° 37′. $\infty\bar{P}\infty$ (*c*); 0P (*u*) 95° 23′. Cl. *c* and *u*. Twin-face *c*; chiefly spheroidal and radiating fibrous. H. = 5; G. = 2·74 to 2·88. Translucent; crystals pearly; fibres silky. Pale green to yellowish white. Sol. in h. acid, leaving silica. C.c.: 54·2 silica, 33·7 lime, 9·4 soda, and 2·7 water. Ratho, Corstorphine, Castle Rock, and Arthur's Seat, Edinburgh; Kilsyth, Stirling; Knockdolian and Lendalfoot, Ayrshire; Skye; Montebaldo; Monzoni Valley in Tyrol.

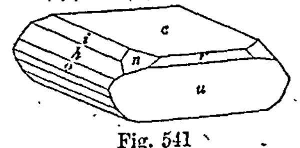


Fig. 541

599. Walkerite, $4\dot{C}a\dddot{S}i+\dot{M}g\dddot{S}i+\dot{N}a\dddot{S}i_2+2\dot{H}$.

Like pectolite, but columnar. H. = 4·5; G. = 2·7. Flesh-coloured. Lustre pearly to greasy. C.c.: silica 53·7, lime 28·6, magnesia 5·1, soda 7·9, water 4·6. Corstorphine Hill, Burntisland.

600. Xonotlite, $4\dot{C}a\dddot{S}i+\dot{H}$.

Massive. H. = 6; G. = 2·6 to 2·7. Pink, white, and grey. Tough;

fracture conchoidal and splintery. C.c.: silica 49·8, lime 43·5, protoxide of manganese 2·3, protoxide of iron 2·9, water 3·7. Killinichen and Torosay (Mull), Xonotla (Mexico).

601. TOBERMORITE, $3(\dot{C}a_4, \dot{H})\ddot{S}i_5 + 2\frac{1}{2}\dot{H}$.

Massive, fine granular; translucent; fracture hackly. H. = 5; G. = 2·4. Pale pink. C.c.: silica 49·8, lime 37·2, water 12·9. Tobermory (Mull), Dunvegan (Skye).

602. OKENITE, $\dot{C}a\dot{H}\ddot{S}i_2 + \dot{H}$.

Right prismatic. ∞P 122° 19′. Usually fine fibrous; radiating. H. = 5; G. = 2·28 to 2·36. Pellucid; slightly pearly. Yellowish to bluish white. In powder easily sol. in h. acid, leaving gelatinous flakes after ignition. C.c.: 56·6 silica, 28·4 lime, and 17 water; an apophyllite without the fluorine. Disco Island, Faroes, and Iceland.

603. APOPHYLLITE, $8(\dot{C}a\ddot{S}i + 2\dot{H}) + KF$.

Pyramidal. P 120° 56′. P, ∞P∞ (m), 0P (o), ∞P2 (r). Rarely lamellar. Cl. o, perfect. Brittle. H. = 4·5 to 5; G. = 2·3 to 3·4. Transparent; vitreous. On o pearly (*Ichthyophthalmite*). Colourless, rarely pink, green, red, brown, and yellow. B.B. exfoliates, intumesces, and melts to white enamel. Sol. in h. acid, leaving silica. C.c.: silica 50·3, lime 24·7, water 15·9;

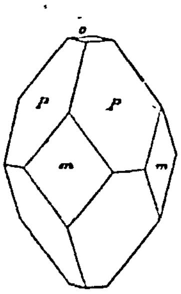


Fig. 542.

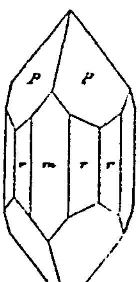


Fig. 543.

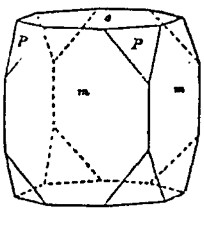


Fig. 544.

potassium 4·3, fluorine 2·1. Dunvegan and Storr, Skye (*fig. 544*); Chapel, Fife; Corstorphine (fig. 542) and Ratho, near Edinburgh; Kilsyth, Bowling, Kilpatrick; Port Rush, Ireland. In the form P (fig. 79), grass-green at Oxhaveer, Iceland (*Oxhaverite*); Utö, Sweden; Andreasberg and Faroes (pink); Faroes, and Poonah in India (green). Internal structure tesselated, being built up of wedge and lenticular forms with varying refractive indices, hence exhibiting a beautiful structure with polarized light.

604. GYROLITE, $(\frac{2}{3}\dot{C}a + \frac{1}{3}\dot{H})\ddot{S}i + \dot{H}$.

Lamellar, radiate, spherical, and investing. H. = 3 to 4. Pearly. Bluish white to cream-coloured. Transparent, rapidly becoming opaque. C.c.: silica 53·3, lime 32·9, water 13·8. Quiraing, Lyndale, and Storr, Skye; Loch Screden and Carsaig, Mull; Canna; Karartut, Niakornak, and Disco; Faroes; Nova Scotia.

605. ANALCIME, $\ddot{A}l\ddot{S}i_3 + \dot{N}a\ddot{S}i + 2\dot{H}$.

Cubic. ∞O∞; 2O2. Fracture uneven. H. = 5·5; G. = 2·1 to 2·28. Colourless, white, flesh-red, scarlet. Vitreous; transparent. B.B. melts without frothing to a clear vesicular glass. Decomposable with gelatinization in h. acid. C.c.: 54·5 silica, 23·3 alumina, 14·1 soda, 8·2 water. Walls, Orkney; Talisker, Skye; Sanda, and Hebrides generally. Transparent at Eigg, and Elie, Fife; scarlet at Bowdens, Kincardine; opaque white at Glen Farg, Salisbury Crags, and Dumbarton; Giant's Causeway, Seisser Alp in Tyrol, Cyclopean Islands (fig. 545), Faroes, Iceland, and Nova Scotia. *Eudnophite* is a variety. Pectolite (sp. 598) occurs pseudomorphous after analcime, in large crystals of a, n, at Ratho, Edinburghshire.

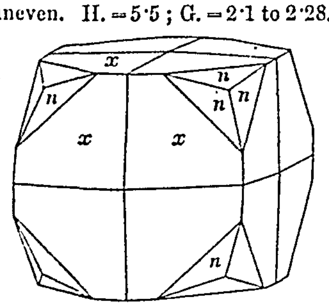


Fig. 545.

606. POLLUX, $3(\ddot{A}l\ddot{S}i_3 + (\dot{C}s\frac{2}{3}, \dot{N}a\frac{1}{3})\ddot{S}i) + 2\dot{H}$.

Cubic. ∞O∞; 2O2 (fig. 546). Also massive. Gum-like externally. Brittle, with traces of cleavage. Fracture conchoidal. H. = 5·5 to 6·5; G. = 2·86 to 2·9. Colourless. Vitreous. Sol. in h. acid. C.c.: silica 44, alumina 16, oxide of cæsium 34, soda 2·5, water 2·4. Elba. The only mineral which contains cæsium in quantity.

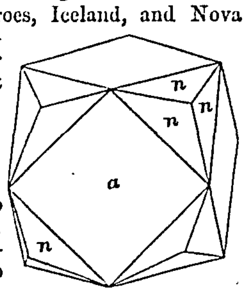


Fig. 546 (sp. 606).

607. FAUJASITE, $2\ddot{A}l\ddot{S}i_3 + (\dot{C}a\dot{N}a)_2\ddot{S}i_3 + 18\dot{H}$.

Cubic; in octahedrons with the icositetrahedron $\frac{6}{5}O\frac{6}{5}$. Fracture uneven; brittle. H. = 7; G. = 1·92. Transparent; vitreous to adamantine. White to brown. Sol. in h. acid. C.c.: 46·8 silica, 16 alumina, 4·4 lime, 4·8 soda, 28 water. Kaiserstuhl in Baden, Annerod near Giessen, Eisenach, Marburg.

608. CHABASITE (*Lime-Chabasite*), $\ddot{A}l\ddot{S}i_3 + \dot{C}a\ddot{S}i + 6\dot{H}$.

Rhombohedral; R 94° 46.′ $\frac{16}{15}R\frac{4}{5}$; $-\frac{1}{2}R$ (r); $-2R$ (e); ∞P2 (a). Twins very common (generally intersesting), on faces ∞P and

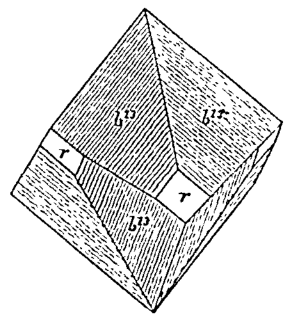


Fig. 547.

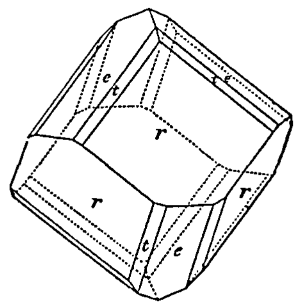


Fig. 548.

P̆∞. Primary rhombohedron is sometimes twinned with a crystal with faces r, e, s. Cl. r perfect. H. = 4 to 4·5; G. = 2 to 2·2. Transparent or translucent; vitreous. Colourless, and brownish,

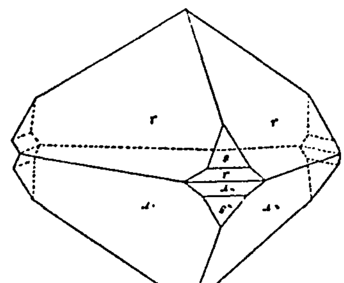


Fig. 549.

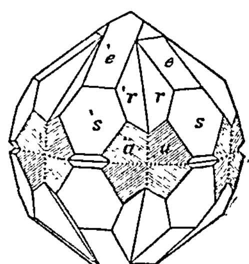


Fig. 550.

yellowish, brick-, and flesh-red. Sol. in h. acid, leaving silica. C.c.: silica 47·8, alumina 20·8, lime 10·7, water 21·3. Lyndale (figs. 547, 548, 549), Talisker (figs. 176, 550, sometimes flesh

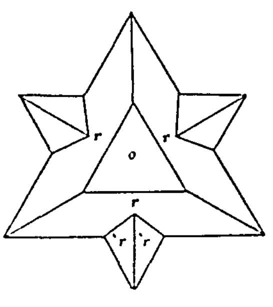


Fig. 551.

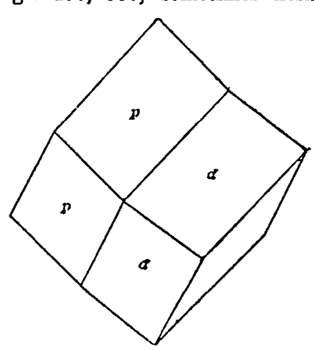


Fig. 552.

colour), and Storr, Skye (figs. 547, 548); Port Glasgow and Kilmalcolm (pink and brown); Giant's Causeway and Magee Island (red), Faroes, Iceland, Aussig, Andreasberg (fig. 551). *Haydenite* in twinned rhombohedra, with p : p 95° to 97° and p : d 170° reentering (fig. 552), from Fassa and Maryland, is similar. *Phacolite* is chabasite in twins of $\frac{4}{3}$P2, ∞P2, R, $-\frac{1}{2}$R at the Giant's Causeway (fig. 154). At Richmond in Victoria they occur as in fig. 553, $-2R$ (n), $-\frac{2}{3}R$ (r), $\frac{4}{3}$P2 (t), 0P (c); polar edge, $\frac{4}{3}$P2 145°. In this, half of the lime is replaced by soda.

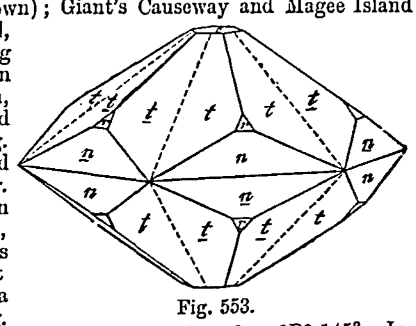


Fig. 553.

609. GMELINITE (*Soda-Chabasite*), $\ddot{A}l\ddot{S}i_3 + \dot{N}a\ddot{S}i + 6\dot{H}$.

Hexagonal. R 112° 26′; P 79° 54′. Combination P, 0P, ∞P

(figs. 554, 556). Faces of P striated parallel to the polar edge, those of the prism horizontally (fig. 555). Cl. ∞P distinct. Gelatinizes with h. acid. C.c.: 47·6 silica, 19·7 alumina, 12 soda, 20·7 water. Certain crystals seem to indicate twinning. Talisker in Skye (twins of fig. 555), Glenarm in Antrim (fig. 555), Vicenza, Pyrgo in Cyprus, Cape Blomidon in Nova Scotia.

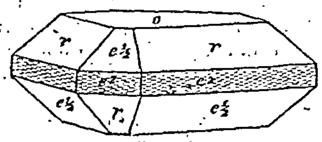


Fig. 554.

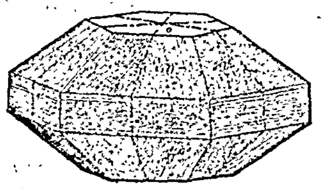


Fig. 555.

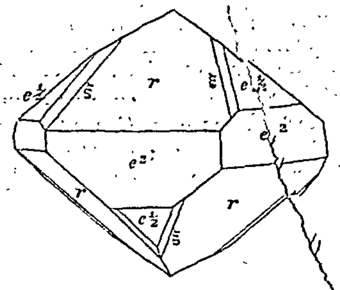


Fig. 556.

610. Levyne, $\dddot{A}l\ddot{S}i_2 + \dot{C}a\ddot{S}i + \dot{H}5$.

Rhombohedral; R (s) 79° 29′; $-\frac{1}{2}$R (r) 106° 3′; 0R (o). Forms intersecting twins as in fig. 557. H. = 4; G. = 2·1 to 2·2. Colourless and white. C.c.: silica 43·8, alumina 23·8, lime 9·7, water 21. Storr in Skye (o, s), Ireland (at Glenarm, Island Magee, Londonderry, &c.), Iceland, Dalsnypen, and Naalsö in the Faroes.

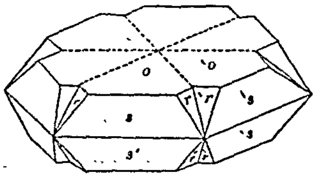


Fig. 557.

611. Herschelite, $\dddot{A}l\ddot{S}i_3 + (\dot{C}a\dot{N}a)\ddot{S}i + 5\dot{H}$.

Hexagonal prisms (c) surmounted by two trihedral pyramids of a_7 and one of $a\frac{11}{5}$ (fig. 558). $a_7 : c$ 122° 8′; $a\frac{11}{5} : c$ 107° 26′; c striated horizontally. Cl. c; fracture conchoidal; transparent; vitreous. White or colourless. H. = 5·5; G. = 2·06. C.c.: silica 47, alumina 21·2, lime 5·2, soda 4·8, potash 2, water 17·86. Aci-Castello and Palagonia in Sicily, Yarra in Australia.

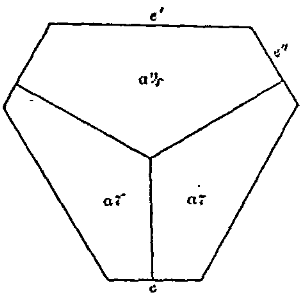


Fig. 558 (sp. 611).

612. Laumontite (*Leonhardite*), $\dddot{A}l\ddot{S}i_3 + \dot{C}a\ddot{S}i + 4\dot{H}$.

Oblique prismatic, C 80° 42′. ∞P (m) 86° 16′. ∞P : $-\infty\bar{P}$ (c) 113° 30′; P∞ (x_2) : $-\infty\bar{P}$ 111° 14′; $c : a$ 125° 41′; $a : b$ 90°; $e : z$ 149° 15′. Twin face a. Cl. m, perfect; very brittle. H. = 3 to 3·5; G. = 2·2 to 2·3. Pellucid when fresh; vitreous; pearly on cl. White, cream-coloured, brick-red. Decomposes rapidly through loss of water. B.B. intumesces, and melts first to a white enamel, ultimately to a clear glass. Gelatinizes in h. acid. C.c: silica 50·9, alumina 21·8, lime 11·9, water 16·3. Rapidly loses 1 equivalent or 3·86 per cent. of water, and becomes friable (*Hypostilbite*). Kilfinichen, Mull (fig. 559); Storr and Quiraing, Skye (hypostilbite); Tod Head, Snizort, Glen Farg (red); Bowling, Dumbarton (twins of m, c); Huelgoat in Brittany; Prague, Falun, Iceland, Faroes, Nova Scotia. *Caporcianite* from Tuscany has only 3 water.

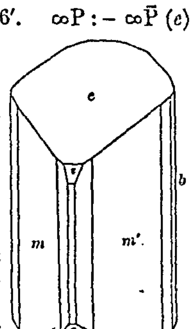


Fig. 559.

613. Epistilbite (*Reissite*), $\dddot{A}l\ddot{S}i_3 + \dot{C}a\ddot{S}i_3 + 5\dot{H}$.

Oblique prismatic, C 54° 53′. ∞P (m) 135° 10′; P∞ (t) 109° 46′; $\frac{1}{2}$P(s) 147° 40′ (fig. 560). Hemitropes united by m, with twins of the same united by the brachydiagonal (a). Cl. brachydiagonal, perfect. H. = 3·5 to 4; G. = 2·3 to 2·4. Pellucid; vitreous; pearly on cl. Colourless. Sol. without gelatinizing. C.c.: silica 59, alumina 17·5, lime 9, soda 1·5, water 14·5. Talisker in Skye (m, t, a); Hartlepool (in twins), Iceland, Faroes, Silesia, Viesch in Valais, Nova Scotia, and New Jersey.

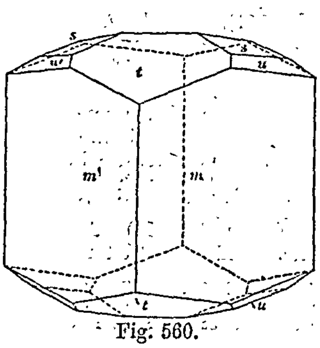


Fig. 560.

614. Heulandite, $\dddot{A}l\ddot{S}i_3 + \dot{C}a\ddot{S}i_3 + 5\dot{H}$.

Oblique prismatic, C 63° 40′. P°∞ (p) 50° 20′; 2P (z); $\frac{2}{3}$P (u); 2P^c∞ (r); 3P^c∞ (s); $\infty\bar{P}\infty$; ∞P^c; 0P. $z : z$ 136° 4′; $u : u$ 146° 52′. Crystals elongated along each of the axes present very varying forms, but generally tabular. Cl. clinodiagonal, perfect; pearly on this, vitreous on others; brittle. H. = 3·5 to 4; G. = 2·1 to 2·2. Transparent to translucent; colourless, white, brick-red, rose, green, hair-brown. B.B. melts with exfoliation and intumescence to a white enamel. Sol. in h. acid, leaving silica. Storr and Talisker, Skye (fig. 562); Sanda; Kilmalcolm; Catterline, Kincardine (fig. 563); Kilpatrick Hills (p, m, n, z, u, r, s) and Kintyre (red); Iceland, Faroes, Fassa Valley, Nova Scotia, Baltimore (*Beaumontite*) (p, m, n, z, t); Vindhya Mountains in India (fig. 564).

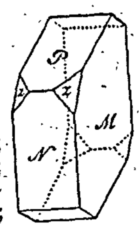


Fig. 561.

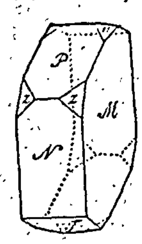


Fig. 562.

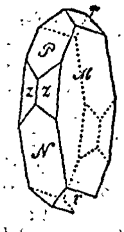


Fig. 563.

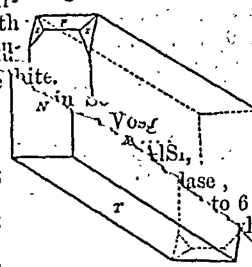


Fig. 564.

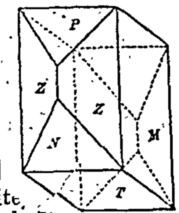


Fig. 565.

(fig. 565)

615. Brewsterite, $\dddot{A}l\ddot{S}i_3 + \dot{R}\ddot{S}i_3 + 5\dot{H}$. $\dot{R} = (\frac{4}{7}\dot{S}r + \frac{2}{7}\dot{B}a + \frac{1}{7}\dot{C}a)$.

Oblique prismatic, C 86° 56′. ∞P°∞ (a); ∞P^c∞ (b); 0P (o); nP^c∞ (e); ∞P (m); ∞P^{c}2 (c); ∞P$^c\frac{3}{2}$ (t). $e : e$ 173° 10′ (fig. 566). Cl. clinodiagonal, perfect; pearly on do., vitreous on others; pellucid. H. = 5 to 5·5; G. = 2·5 to 2·45. Colourless, yellow, or brown. Sol. with gelatinization in h. acid. C.c.: 54·3 silica, 15 alumina, 9 strontia, 6·6 baryta, 1·3 lime, 13·5 water. Strontian, Freiburg in the Breisgau, Pyrenees.

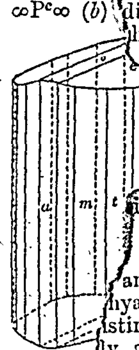


Fig. 566

616. Phillipsite, $\dddot{A}l\ddot{S}i_3 + (\dot{C}a, \dot{K})\ddot{S}i + 5\dot{H}$.

Oblique prismatic, C 55° 1′. ∞P (m); ∞P^c∞ (b); 0P (c). Polar edges 120° 42′ and 119° 18′. Faces b and m striated parallel to the intersections. Apparently always twinned; generally these duplicated by intersection on face b or face c (figs. 567, 568), and frequently arranged so that three of the above double twins in right angles to one another, forming the cruciform

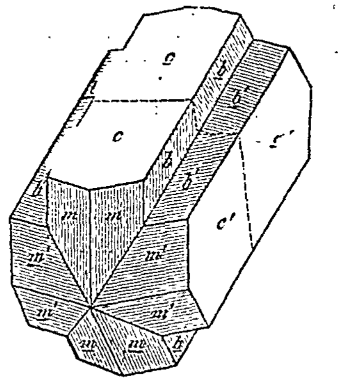


Fig. 567.

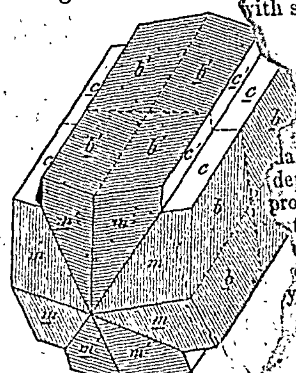


Fig. 568.

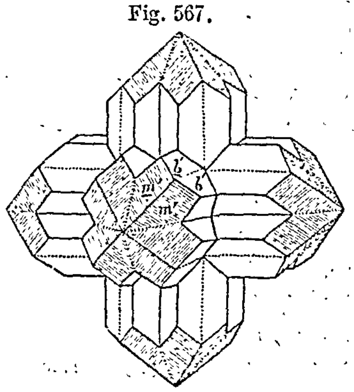


Fig. 569.

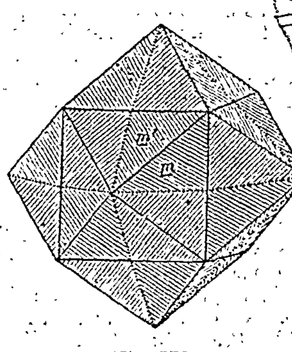


Fig. 570.

When the prismatic faces of these are short, the faces m of the

intersecting individuals fall nearly into one plane, presenting the form fig. 570; when long, fig. 190. Brittle; fracture uneven. H. = 4·5; G. = 2·15 to 2·2. Gelatinizes in h. acid. C.c.: silica 48·6, alumina 20·2, lime 7·3, potash 6·2, water 17·7. Giant's Causeway, Giessen, Marburg, Cassel, Capo di Bove, Vesuvius, Iceland.

617. HARMOTOME, $\dddot{\rm Al}\ddot{\rm Si}_3+\dot{\rm Ba}\ddot{\rm Si}_2+5\dot{\rm H}$.

Oblique prismatic, C 55° 10′. ∞P (s); ∞P ∞ (b); 0P (a). Forms like phillipsite, but more frequently in simple twins. Physical properties like phillipsite, but G. = 2·3 to 2·5, and fuses

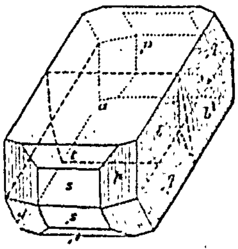


Fig. 571.

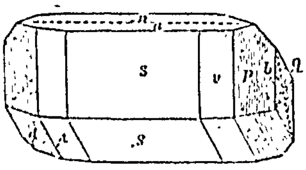


Fig. 572.

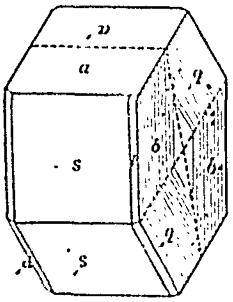


Fig. 573.

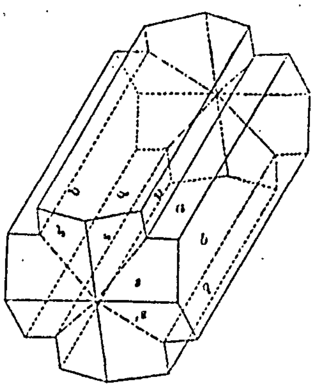


Fig. 574.

with difficulty. Difficultly sol. in h. acid. C.c.: 46·5 silica, 15·9 alumina, 23·7 baryta, and 13·9 water. Strontian, transparent (*Morvenite*, fig. 572) and opaque (figs. 571, 573); Glen Arbuck (fig. 574) and Bowling in Dumbarton; Corstorphine near Edinburgh; Andreasberg, Kongsberg, Oberstein.

618. STILBITE, $\dddot{\rm Al}\ddot{\rm Si}_3+\dot{\rm Ca}\ddot{\rm Si}_3+6\dot{\rm H}$.

Oblique prismatic, but with right prismatic habit; C 50° 49′. ∞P̄∞ (a); ∞P∞ (b); P (r); ∞P2 (m); 0P (p). Cl. a, perfect. H. = 3·5 to 4; G. = 2·1 to 2·2. Transparent; vitreous. Pearly on a. Colourless, white, yellow, pale brown, brick-red. Decomposed by h. acid, leaving silica. C.c.: silica 57·5, alumina 16·4, lime 8·9 water 17·2. Storr and Talisker in Skye (a, b, p) (fig. 575), and in Hebrides (colourless); Arran and Kilmalcolm (pale brown); Long Craig (Dumbarton) and Kinneff (Kincardine) (brick-red); Iceland, Faroes, Andreasberg, Vindhya Mountains, Wellington Mountains (Australia), Nova Scotia.

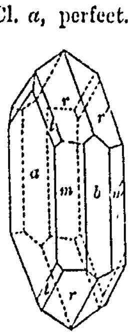


Fig. 575, (sp. 618).

619. PUFFLERITE, $\dddot{\rm Al}\ddot{\rm Si}_3+\dot{\rm Ca}_2\ddot{\rm Si}_3+5\dot{\rm H}$.

Fibrous globular concretions, with vitreous surface. H. = 4; G. = 2·21. Greyish white. Transparent. C.c.: silica 52·8, alumina 16·3, lime 11·2, water 17·2. Pufflatsch in the Seisser Alp.

620. EDINGTONITE, $4\dddot{\rm Al}\ddot{\rm Si}_2+3\dot{\rm Ba}\ddot{\rm Si}+12\dot{\rm H}$.

Pyramidal; hemihedral with inclined faces. P 87° 19′; ½P (n) 129° 8′; ∞P (a); polar edges 92° 51′ (fig. 576). Cl. a, perfect; fracture uneven. H. = 4 to 4·5; G. = 2·7 to 2·71. Translucent; vitreous. Colourless. C.c.: silica 37·3, alumina 23·75, baryta 26·52, water 12·46. Kilpatrick Hills in Dumbartonshire.

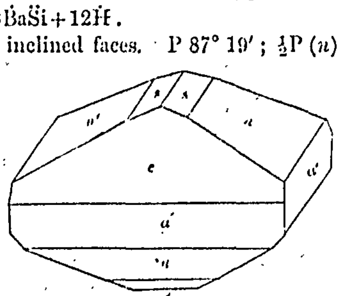


Fig. 576 (sp. 620).

621. FORESITE, $2\dddot{\rm Al}\ddot{\rm Si}_2+(\dot{\rm Na},\ \dot{\rm Ca}_3)\ddot{\rm Si}_2+6\dot{\rm H}$.

Right prismatic. ∞P̄∞; ∞P̆∞; 0P. Cl. brachydiagonal, perfect; lustre thereon pearly. G. = 2·4. White. C.c.: silica 50, alumina 27·4, lime 5·5, soda 1·4, water 15·1. San Piero in Elba.

622. NATROLITE, $\dddot{\rm Al}\ddot{\rm Si}_2+\dot{\rm Na}\ddot{\rm Si}+2\dot{\rm H}$.

Right prismatic. ∞P (m) 91°; P (o); polar edges 143° 20′ and 144° 40′, middle edge 53° 20′; ∞P̆∞ (b); ∞P̄∞ (a). Radiating acicular crystals, often fibrous. Cl. ∞P, perfect. H. = 5 to 5·5; G. = 2·17 to 2·26. Pellucid; vitreous. Colourless, ochre-yellow, reddish. Is not pyro-electric. B.B. melts quietly to a clear glass, colouring flame yellow. Sol. in oxalic acid. C.c.: 47·2 silica.

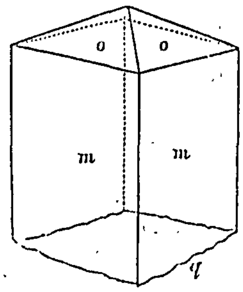


Fig. 577.

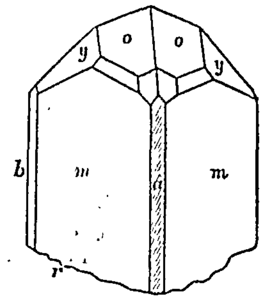


Fig. 578.

27 alumina, 16·3 soda, 9·4 water. Glen Farg (fig. 577), (colourless and reddish), Tantallon Castle (fig. 578), Dumbarton, Bowling (green), Campsie, Bishopton, Glenarm and Port Rush (Ireland), Auvergne, Hesse, Hohentwiel in Swabia, Norway. *Crocalite* is red, fibrous, and investing; Kintyre, Forfarshire, Wemyss Bay, and the Urals.

623. SCOLECITE, $\dddot{\rm Al}\ddot{\rm Si}_2+\dot{\rm Ca}\ddot{\rm Si}+3\dot{\rm H}$.

Oblique prismatic, C 89° 6′. ∞P (m) 91° 35′; P (o) 144° 20; −P. Prismatic and acicular crystals. Twins common, on face ∞P̊∞, one face with feathered striæ. Cl. ∞P, perfect. H. = 5 to 5·5; G. = 2·2 to 2·3. Pellucid; vitreous; pyro-electric. White to reddish white. B.B. twists in a vermicular manner; melting readily to a porous glass. Only partially sol. in oxalic acid. C.c.: silica 45·8, alumina 26·2, lime 14·3, water 13·7. Staffa; Loch Screden, Mull; Talisker, Skye; Berufiord, Iceland (fig. 579); Faroes; Vindhyas, India. Natrolite and scolecite pass into one another. There are two definite intermediates—*Fargite*, consisting of two equivalents of natrolite and one of scolecite, and *Mesolite*, consisting of one of the former and two of the latter. The first of these occurs at Glen Farg and at Bishopton (*Galactite*); the second is the ordinary radiated zeolite of the amygdaloids of the Tertiary igneous rocks of the Hebrides and the Faroes. It there occurs in matted crystals of extreme tenuity (*Cottonstone*), also in delicate feathery tufts; in Renfrewshire in spheres with an internally radiated structure, and also in needle form and in downy tufts.

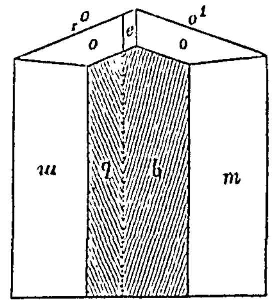


Fig. 579.

624. GISMONDINE, $\dddot{\rm Al}\ddot{\rm Si}+\dot{\rm Ca}\ddot{\rm Si}+4\dot{\rm H}$.

Pyramidal. P (b) 92° 30′; polar angle 118° 31′; ∞P∞ (fig. 580). Cl. P. H. = 5, on edges and angles 5 to 6; G. = 2·26. Translucent; vitreous. Bluish white to pale red. C.c.: silica 35·9, alumina 27·3, lime 13·1, potash 2·8, water 21·1. Island Magee and Larne, Ireland; Vesuvius, Aci-Castello, and Capo di Bove; Schiffenberg near Giessen; Schlauroth near Görlitz.

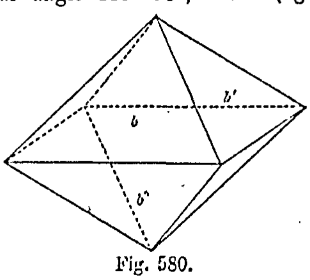


Fig. 580.

625. ZEAGONITE, $\dddot{\rm Al}\ddot{\rm Si}+(\dot{\rm Ca}\dot{\rm K})\ddot{\rm Si}+4\dot{\rm H}$.

Right prismatic. P polar angle 120° 37′ and 121° 44′; middle angle 89° 13′. Crystals like fig. 419. H. = 5, on edges and angles 7; G. = 2·2. Transparent; vitreous. Colourless, white, or bluish. C.c.: silica 44, alumina 23·3, lime 5·3, potash 11·1, water 15·3. Capo di Bove.

626. THOMSONITE, $2\dddot{\rm Al}\ddot{\rm Si}+2(\dot{\rm Ca}\dot{\rm Na})\ddot{\rm Si}+5\dot{\rm H}$.

Right prismatic. ∞P (m) 90° 26′; ∞P̄∞ (a); ∞P̆∞ (b); ⅓P̆∞ (y); P̄∞ (r); $\frac{1}{18}$P̆∞ (x). x : x 177° 34′ 20″. Cl. macrodiagonal and brachydiagonal, both perfect. H. = 5 to 5·5; G. = 2·35 to 2·38. Translucent; vitreous; pearly on macrodiagonal. Colourless. B.B. difficultly fusible with intumescence to a white enamel. Sol. with gelatinization in h. acid. C.c.: silica 38·7, alumina 30·8, lime 13·4, soda 4·4, water 13·1. Lochwinnoch, Renfrew; Kilpatrick (fig. 582); Quiraing and Talisker (sometimes

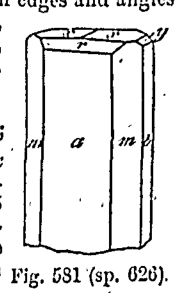


Fig. 581 (sp. 626).

massive-granular); Rathlin and Magee Island, Ireland; Faroes, Vesuvius (fig. 581), Sicily, Bohemia, Tyrol, Nova Scotia.

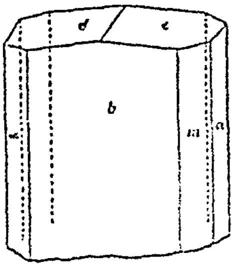


Fig. 582 (sp. 626).

Faroelite is a variety with 42·5 of silica. It replaces thomsonite generally in Tertiary igneous rocks, occurring at Storr and elsewhere in the Hebrides, Faroes, Iceland, and Nova Scotia. The angle of the vertical prism is within 8′ of that of thomsonite. It contains an equivalent more silica.

627. PREHNITE, $\dddot{Al}\dddot{Si}+2\dot{Ca}\dddot{Si}+\dot{H}$.

Right prismatic. ∞P (*m*) 99° 58′; 0P (*c*); $3\breve{P}\infty$ (*e*) 33° 26′; $\frac{4}{3}\bar{P}\infty$ (*v*) 90° 32′; $\infty\breve{P}\infty$ (*a*); $\infty\bar{P}\infty$ (*b*); P (*s*). Crystals either tabular of *c*, or prismatic along both the vertical and the brachydiagonal axes, hence varying much in form. Also in fan-shaped and botryoidal aggregations. Cl. *c*, perfect; pearly thereon, vitreous elsewhere. H. = 6 to 7; G. = 2·8 to 3. Transparent to translucent. Colour-

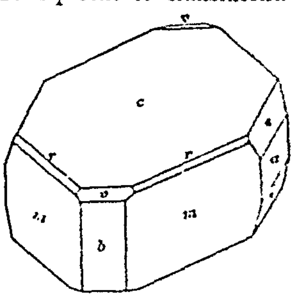


Fig. 583.

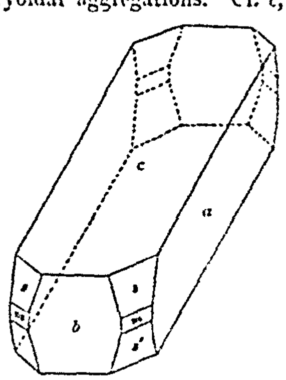


Fig. 584.

less, but generally green of bright but pale tints, also lemon-yellow. Becomes electrically polar by heat. B.B. intumesces greatly, melting to a porous enamel. Decomposed by h. acid. C.c.: silica 43·6, alumina 24·9, lime 27·1, water 4·4. Glen Gairn, Aberdeen (fig. 583); Skye and Mull; Corstorphine Hill (green and pink), Castle Rock (white), and Salisbury Crags (yellow), Edinburgh; Frisky Hall, Dumbartonshire (fig. 584); Hartfield Moss, Renfrew (botryoidal); Cornwall; Dauphiné; Tyrol: Cape of Good Hope; China (*Fu*).

628. FRIEDELITE, $\dot{Mn}_4\ddot{Si}_3+2\dot{H}$.

Rhombohedral; R 123° 42′. 0R; ∞R. Tabular habit, and in granular aggregates. Cl. basal, perfect. H. = 4 to 5; G. = 3·1. Rose-red, with paler streak. C.c.: silica 36, protoxide of manganese 53, lime 2·96, water 7·9. Adervielle on the Neste de Louron (Pyrenees).

HYDROUS SILICATES OF ALUMINA.

These are probably for the most part products of decomposition of felspars under atmospheric exposure.

629. KAOLIN (*Porcelain Earth*), $\dddot{Al}\ddot{Si}_2+2\dot{H}$.

Massive; in beds and veins. Fracture uneven; fine earthy, very soft, sectile, and friable. H. = 1; G. = 2·2. Opaque, dull. White or grey, inclining to blue, green, yellow, or red. Feels meagre, not greasy when dry, and plastic when wet. B.B. infusible. Not affected by h. acid, but decomposed by warm s. acid, leaving silica. C.c. very variable, but approximates to 46 silica, 40 alumina, and 14 water. Chiefly a product of the decomposition of orthoclase, or of granite, porphyry, and other rocks containing that mineral. Cornwall and Devonshire in England are the chief European localities for the kaolin used in manufacturing porcelain.

Clays are merely varieties of kaolin, mixed with quartz-sand, carbonate of lime, magnesia, and the oxyhydrates of iron. Often 40 to 50 silica, 30 alumina, 13 to 20 water, and 4 iron peroxide, with lime and potash. In the fire they are infusible, burning hard. Generally they are compact and friable, of white, yellow, red, blue, grey, or brown colours. Their specific gravity varies from 1·8 to 2·7. The following are varieties. *Pipe-clay*, greyish or yellowish white, with a greasy feel, adheres strongly to the tongue, when wet is very plastic and tenacious, and in the fire burns white. Abundant in Devonshire, and in the Trough of Poole in Dorsetshire; in France, Belgium, and Germany. Used for manufacturing tobacco-pipes and similar articles. *Potter's Clay*, red, yellow, green, or blue, becoming yellow or red when burnt; more easily fused than the former, and often effervesces with acids. That used in the potteries in England comes chiefly from Devonshire. *Loam*, coarser and more impure, with more sand, and consequently less plastic. *Shale* or *Slate Clay*, greyish black, and much mixed with bituminous or carbonaceous matter. *Bituminous Shale*, known by its shining resinous streak. *Black Chalk*, with more carbon, leaves a black mark on paper. *Iron Clay* contains much peroxide of iron, is reddish-brown, and forms the basis of many amygdaloids and porphyries.

630. NACRITE, $\dddot{Al}\ddot{Si}_2+2\dot{H}$.

Right prismatic; minute six-sided tables in fan-like group; and scaly. H. = 0·5 to 1; G. = 2·35 to 2·6. Glimmering to pearly, snow-white or yellowish white. C.c.: silica 46·3, alumina 39·8, water 13·9. A crystalline form of kaolin. Fins in Allier, Mons, Freiberg, Pennsylvania, and coal formation commonly.

631. LITHOMARGE.

Kaolinic substances, compact, earthy, and pseudomorphous. H. = 2·5 to 3; G. = 2·4 to 2·6. White, yellow, or red. Greasy, adheres to tongue. Klausthal, Harz, &c. Similar are *Carnat*, *Myelin*, *Melopsite*.

632. HALLOYSITE, $\dddot{Al}\ddot{Si}+4\dot{H}$.

Massive and reniform. H. = 1·5 to 2·5; G. = 1·9 to 2·1. Translucent when moist. Bluish white, green, or yellow. C.c.: 41·5 silica, 34·4 alumina, 24·1 water. Hospital Quarry near Elgin, on the Tweed, Liége, Tarnowitz, Eifel (*Lenzinite*). *Fuller's Earth* may be an impure ferruginous variety. Maxton in Scotland, Reigate and Maidstone in England, Saxony, Bohemia, &c.

633. GLAGERITE, $\dddot{Al}_2\ddot{Si}_3+6\dot{H}$.

H. = 1; G. = 2·35. Bergnersreuth. *Malthazite*, from Steindörfel near Bautzen, has less alumina.

634. KOLLYRITE, $\dddot{Al}_2\ddot{Si}+9\dot{H}$.

H. = 1 to 2; G. = 2. Also similar. Schemnitz, Pyrenees, and Saxony. *Scarbroite* from Scarborough has $10H_2O$.

635. MILOSCHIN.

Conchoidal or earthy. H. = 2; G. = 2·1. Indigo-blue to celadon-green; has 2 to 4 chrome oxide. Rudnik in Servia.

636. MONTMORILLONITE, $\dddot{Al}_2\ddot{Si}_7+2\dot{H}$.

Massive. Rose-red. Montmorillon and elsewhere in France, Poduruoj in Transylvania.

637. RAZOUMOFFSKIN, $\dddot{Al}\ddot{Si}_3+3\dot{H}$.

From Carinthia. *Chrome Ochre*, with 2 to 10 per cent. of chrome oxide, from Waldenburg in Silesia and Creusot in France, is similar.

638. CIMOLITE, $\dddot{Al}_2\ddot{Si}_9+6\dot{H}$.

Pseudomorphous after augite. Bilin, Limburg, Kaiserstuhl, Argentiera and Milo.

639. ALLOPHANE, $\dddot{Al}\ddot{Si}+5\dot{H}$.

Botryoidal and reniform. Fracture conchoidal; brittle. H. = 3; G. = 1·8 to 2. Pellucid; vitreous. Pale blue, white, green, or brown. Colour due to copper. Charlton, Woolwich, Baden, and Bonn.

640. PYROPHYLLITE, $\dddot{Al}\ddot{Si}_4+\dot{H}$.

Right prismatic, but radiated, foliated. Cl. perfect; flexible, sectile. H. = 1; G. = 2·8 to 2·9. Translucent, pearly. Light verdigris-green to yellowish white. B.B. swells up with many twistings to a white infusible mass. C.c.: 67 silica, 28 alumina, and 5 water. Urals, Spa, Morbihan, Westana in Sweden, Carolina, and Brazil. *Talcosite*, from Heathcote in Victoria, has silica and alumina about equal.

641. ANAUXITE, $\dddot{Al}\ddot{Si}_4+3\dot{H}$.

Granular. H. = 2 to 3; G. = 2·2 to 2·4. Translucent, pearly. Greenish white. C.c.: 60·5 silica, 26 alumina, and 13·5 water. Bilin in Bohemia.

HYDROUS SILICATES OF ZIRCONIA, THORIA, &c.

642. MALACONE, $3\ddot{Zr}\ddot{Si}+\dot{H}$.

Pyramidal. P 83° 30′. Typical form $\infty P\infty$, P, ∞P. H. = 6; G. = 3·9 to 4·1. Conchoidal fracture. Lustre vitreous. C.c. same as zircon, but with 3 of water in the Hitterö variety and over 9 in that from Finland. Has a surface opalescence, and may be altered zircon. Hitterö, Chanteloube (near Limoges), near Dresden, Rosendal, Finland, Miask.

643. EUCRASITE.

Right prismatic (?). H. = 4·5 to 5; G. = 4·39. Lustre greasy. Blackish brown; streak brown. Translucent on edges. Fracture uneven; brittle. C.c. very complex: silica 16, thoria 36, cerium protoxide 5·5, peroxide 6, lanthania 2·4, yttria 4·3, erbia 1·6, titanic acid 1·8, ferric oxide 4·25, alumina 1·8, water 9. Barkevig near Brevig.

644. THORITE, $\ddot{Th}\ddot{Si}+2\dot{H}$.

Pyramidal. ∞P : P 133° 30′. Generally massive. H. = 4·5 to 5. G. = 5 to 5·4. Lustre brilliant vitreous; when weathered resinous. Fracture conchoidal when fresh, splintery when weathered. Brownish black to clove-brown. C.c. complex, but essentially 18 silica, 73 thoria, 9 water. In syenite at Lochan

Hacon, and in a boulder on Ben Bhreck in Sutherland, in crystals (fig. 585); Löwö near Brevig, Norway. *Uranothorite*, from Arendal, has 50 per cent. thoria and 10 uranous oxide; found also at Hitterö and at Champlain (U. S.)

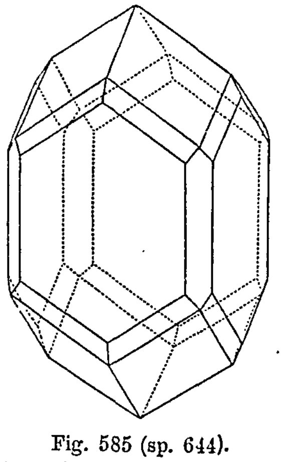


Fig. 585 (sp. 644).

645. ORANGITE, $3\ddot{Th}\dddot{Si}+2\dot{H}$.

Massive. Orange-yellow to cinnamon-red. Other characters like thorite. C.c.: 17 silica, 75 thoria, 7 water. Ben Bhreck, Langesund near Brevig. The mineral from Ben Bhreck passes gradually into thorite, which thus would appear to be altered orangite.

646. TRITOMITE, $\dddot{R}_2\dddot{Si}_3+4\dot{H}$.

Cubic. In tetrahedra. H. = 5·5; G. = 3·9 to 4·66. Lustre vitreous. Dull brown; streak yellowish grey. Subtranslucent. C.c. complex: silica 21, alumina 2·5, ceria 40, lanthania 15, yttria 4·6, lime 4, water 8. Lamö near Brevig.

MAGNESIAN SILICATES.

647. AGALMATOLITE (*Figure Stone*), $4\dddot{Al}\dddot{Si}_3+\dot{K}\dddot{Si}_3+3\dot{H}$.

Massive or slaty. Fracture splintery, rather sectile. H. = 2 to 3; G. = 2·8 to 2·9. Translucent; glimmering. Green, grey, red, and yellow. Feels somewhat greasy, but does not adhere to the tongue. Sol. in s. acid. C.c.: 55 silica, 33 alumina, 7·6 potash, and 5 water; but in many localities magnesian. Calligaig in Sutherland; China, where it is cut into various works of art; also Nagyag in Hungary, and Saxony.

648. ONCOSIN, $2\dddot{Al}\dddot{Si}_2+(\dot{K},\dot{M}g)\dddot{Si}_2+2\dot{H}$.

Fracture uneven or splintery; sectile. H. = 2; G. = 2·8. Translucent; slightly resinous. Apple-green or brown. Sol. in s. not in h. acid. Salzburg.

649. LIEBENERITE.

Hexagonal. ∞P; 0P. Cl. prismatic, perfect; fracture hackly. H. = 3·5; G. = 2·8. Oil-green, bluish green, and greenish grey. Greasy lustre. C.c.: silica 44·7, alumina 36·5, potash 9·9, water 5·5. Monte Viesena near Forno, Predazzo in Tyrol.

650. GIESECKITE.

Hexagonal. ∞P; 0P. Fracture splintery. H. = 3 to 3·5; G. = 2·7 to 2·9. Kangerdluarsuk in Greenland, Diana in New York.

651. KILLINITE, $2\dddot{Al}\dddot{Si}_2+\dot{R}\dddot{Si}_2+3\dot{H}$.

Crystalline, foliated. Cl. along a prism of 135° 44′. G. = 2·65. Greenish grey, yellow, or brownish green. C.c.: 48 silica, 31 alumina, 2·3 protoxide of iron, 6·5 potash, 10 water. Killiney near Dublin.

652. HYGROPHILITE.

Scaly. H. = 2 to 2·5; G. = 2·7. Greenish grey. Lustre and feel greasy. C.c.: silica 48·4, alumina 32·1, protoxide of iron 3·3, potash 5·7, water 9. Sol in h. acid. Halle on the Saale.

653. BRAVAISITE, $\dot{R}_2\dddot{Si}_3+2\dddot{Al}\dddot{Si}_3+4\dot{H}$.

Aggregates of thin plates. H. = 1 to 2; G. = 2·6. C.c.: silica 51·4, alumina 18·9, peroxide of iron 4, magnesia 3·3, potash 6·5, water 13·3. Noyant in Allier.

654. PINITOID.

Massive. Leek- and oil-green. H. = 2·5; G. = 2·8. C.c.: silica 48·5, alumina 28, protoxide of iron 8, potash 5·8, water 4·5. Freiberg and Chemnitz in Saxony.

655. BOLE.

Earthy, in nests and veins. Conchoidal. H. = 1 to 2; G. = 2·2 to 2·5. Opaque; dull resinous; streak shining. Brown, yellow, or red. Feels greasy; some adhere strongly to the tongue, others not at all. In water crackles and falls to pieces. C.c. hydrous silicates of alumina and iron peroxide, in various proportions. Scotland, Ireland, Dransfeld, Clermont in Auvergne. *Stolpenite, Rock Soap, Plinthite, Yellow Earth* or *Felinite, Fetbol*, and *Ochran* are varieties.

656. CARPHOLITE, $\dddot{Al}\dddot{Si}+\dot{M}n\dddot{Si}+2\dot{H}$.

Right prismatic. P 111° 27′. Radiating stellated. H. = 5 to 5·5; G. = 2·9. Translucent; silky; straw- to wax-yellow. B.B. intumesces and fuses to an opaque brown glass. C.c.: silica 38, alumina 29·4, protoxide of iron 2·9, peroxide of iron 4, protoxide of manganese 11·8, water 10·8. Schlaggenwald, Wippra in the Harz, Meuville in the Ardennes.

657. NONTRONITE, $\dddot{Fe}\dddot{Si}_3+5\dot{H}$.

Massive; fracture uneven. H. = 2 to 3; G. = 2 to 2·3. Opaque; dull or glimmering; streak resinous. Straw-yellow or siskin-green. B.B. decrepitates, becomes black and magnetic, but without fusing; sol. and gelatinizes in warm acids. C.c.: 43 silica, 36 iron peroxide, and 21 water, with 3·5 alumina and 2 magnesia. Nontron in France, Harz, and Bavaria. *Chloropal* is similar. B.B. brown. Unghvar in Hungary, and Passau.

658. PINGUITE.

Massive; fracture splintery; sectile. H. = 1; G. = 2·3. Light to dark green. Lustre vitreous. Feels greasy. C.c.: silica 36·9, peroxide of iron 29·5, protoxide of iron 6·1, water 25·1. Wolkenstein, Suhl.

659. HISINGERITE, $\dddot{Fe}_2\dddot{Si}_3+2\dot{F}e\dddot{Si}+9\dot{H}$.

Reniform, and in crusts. H. = 3·5 to 4; G. = 2·6 to 3. Opaque, resinous. Brownish or bluish black; streak liver-brown or yellowish brown. C.c.: various, but 32·5 silica, 33·5 iron peroxide, 15·1 iron protoxide, and 19 water, in the *Thraulite* from Bodenmais. Also Gilling and Riddarhyttan in Sweden, and Breitenbrunn (*Polyhydrite*).

660. BERGHOLZ.

Fine fibrous; glimmering lustre. Wood-brown to green. G. = 2·4. C.c.: silica 55·5, peroxide of iron 19·5, magnesia 15, water 10·3. Sterzing in Tyrol. *Xylite*, probably from the Urals, is similar.

661. UMBER.

Massive; fracture conchoidal. H. = 1·5; G. = 2·2. Liver-brown; streak shining. Mixtures of peroxide of iron, oxide of manganese, and alumina with water. Cyprus. *Hypoxanthite* and *Siderosilicite* are similar.

662. KLIPSTEINITE, $(\dot{R}_3,\dddot{R}_3)_2\dddot{Si}_3+\dot{R}_3\dot{H}_3$.

Compact. H. = 5 to 5·5; G. = 3·5. Liver-brown to black; streak yellow-brown. C.c.: silica 25, peroxide of iron 4, sesquioxide of manganese 57, water 9. Klapperud in Dalecarlia, Herborn near Dillenburg.

663. WOLKONSKOITE.

Amorphous. Horny; bluish green to grass-green. Fracture conchoidal; brittle. C.c.: silica 36, alumina 3, sesquioxide of chromium 19, ferric oxide 10, water 21. Okhansk in Siberia.

664. RÖTTISITE, $3\dot{N}i\dddot{Si}+4\dot{H}$.

Amorphous and reniform. Apple-green to emerald-green. H. = 2 to 2·5; G. = 2·35 to 2·37. C.c.: silica 43·7, nickel oxide 35·9, water 11·2. Röttis near Reichenbach in Saxony. *Komarit* is similar.

665. URANOPHANE, $3\dot{C}a\dddot{Si}+\dddot{U}_5\dddot{Si}_3+18\dot{H}$.

Right prismatic. ∞P 146°; ∞P̄∞; P̆∞; with polar angle 90°. Crystals honey-yellow; when massive leek-green. H. = 2·5; G. = 2·6 to 2·8. C.c.: silica 17, alumina 6·1, oxide of uranium 53·3, lime 5·1, water 15·1. Kupferberg in Silesia.

666. URANOTILE, $\dot{C}a\dddot{Si}+\dddot{U}_3\dddot{Si}_2+9\dot{H}$.

Right prismatic. ∞P 164. In stellate groups. Lemon-yellow. G. = 3·96. C.c.: silica 13·8, oxide of uranium 66·75, lime 5·27, water 12·67. Wölsendorf in Bavaria, Joachimsthal, Mitchel county in North Carolina.

667. BISMUTOFERRITE, $\dddot{Bi}, \dddot{Si}_2, +2\dddot{Fe}, \dddot{Si}$.

Crypto-crystalline; oblique prismatic. Siskin- to olive-green. H. = 3·5; G. = 4·48. C.c.: silica 24, oxide of bismuth 42·8, peroxide of iron 33·1. Schneeberg in Saxony. *Hypochlorite* is a variety containing 13 of bismuth. In a third variety, from Bräunsdorf, antimony replaces bismuth.

SILICATES WITH TITANATES, NIOBATES, &c.

668. SPHENE, $\dot{C}a\dddot{Si}_2+\dot{C}a\dddot{Ti}_2$.

Oblique prismatic, C 85° 22′. ∞P (*l*) 133°2′; $\frac{1}{2}$P°∞ (*x*) 55° 21′; P°∞ (*y*) 34° 21′; ∞P^c∞ (*q*): 0P (*P* or *c*) 90°; ∞P^{c}3 (*M*) 76° 7′; P^c∞ (*r*) 113° 30′; $\frac{2}{3}$P^{c}2 (*n*) 136° 12′; 4P^{c}4 (*s*) 67° 57′. Crystals vary extremely in form, being generally apparently oblique-tabular, from predominance of *n*, which are hemidomes in alternate position on opposite ends; also, but more rarely, prismatic, with dominance of *l* and *M*. Twins frequent. Twin face *c*, and formed by revolution either (*a*) on an axis normal to *c* or (*b*) on a vertical axis; the former very common and usually producing thin tables with a re-entering angle along one side, and sometimes elongated. Occasionally in double twins. Sometimes granular or foliated. Cl. in some (*l*), in others (*r*). H. = 5 to 5·5; G. = 3·4 to 3·6. Semitransparent; adamantine or resinous.

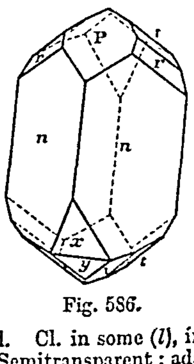


Fig. 586.

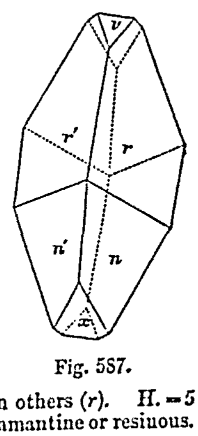


Fig. 587.

Yellow, brown, and green. B.B. fuses with micro-salt in the red. flame, gives reaction for titanic acid. C.c.: silica 30·6, titanic acid 40·8, lime 28·6. In Scotland, typical of syenites and primary limestones. In minute hair-brown crystals in the first; as at Lairg (Sutherland), Achavarasdale (Caithness), and Criffel (Kirkcud-

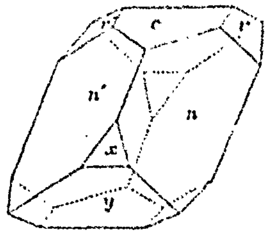


Fig. 588.

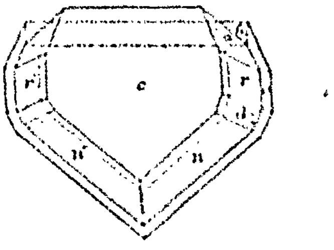


Fig. 589.

bright) (figs. 586 to 588). In the latter often in highly complex twins, yellow to brown, at Shiness (figs. 193, 589), Urquhart, Dalnain, Torbane, &c., also with ilmenite and allanite in exudation veins of grey granite. Dauphiné, Mont Blanc, St Gotthard, Tyrol, Arendal, America. *Greenovite*, flesh-red from Glen Gairn in Aberdeenshire (like 194), and St Marcel in Piedmont; contains manganese at the latter locality.

669. Keilhauite (*Yttrotitanite*), $5(\dot{C}a\dot{Y})(\ddot{S}i\ddot{T}i) + (\dddot{A}l\dddot{F}e)(\ddot{S}i\ddot{T}i)_3$.

Oblique prismatic, C 58°. ∞P 114. Cl. -2P, 135°. H. = 6 to 7; G. = 3·5 to 3·7. Blackish brown; streak greyish yellow. B.B. with borax forms blood-red glass in the red. flame; other features like sphene. C.c.: 29·7 silica, 28·7 titanic acid, 21·1 lime, 10·3 yttria, 6·2 alumina, and 6·5 iron peroxide. Near Arendal.

670. Schorlomite (*Ferrotitanite*), $\dot{C}a_3\ddot{S}i + \dddot{F}e_2\ddot{S}i_3 + \dot{C}a\ddot{T}i_2$.

Cubic; ∞O and 2O2; generally massive; fracture conchoidal. H. = 7 to 7·5; G. = 3·8. Black; streak grey-black; vitreous. C.c.: silica 26, titanic acid 23·3, peroxide of iron 20, lime 29·1. Arkansas, Kaiserstuhl, Ivaara in Finland. Perhaps a titaniferous garnet.

671. Tschewkinite.

Massive; fracture flat conchoidal. H. = 5 to 5·5; G. = 4·5. Opaque, vitreous, splendent. Velvet-black; streak dark brown. B.B. intumesces greatly, becomes porous, and often incandesces; in white heat fuses to black glass; gelatinizes with h. acid. C.c.: 21 silica, 20 titanic acid, 11 iron protoxide, 45 peroxides of cerium metals with perhaps thoria, lime 4. Miask, Coromandel.

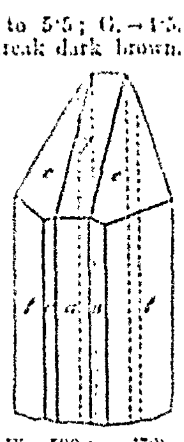


Fig. 590 (sp. 672).

672. Mosandrite.

Oblique prismatic, C 71° 24½′. ∞P (*t*) 88° 36′; ∞P∞2 (*n*); ∞P∞ (*a*); $-$P (*e*) 124° 1′; $-$P∞ (*q*); ∞P∞. *t* : *a* 134° 18′; *n* : *a* 152° 52′; *q* : *a* 138° 2′. Twin face the orthopinacoid. Generally massive. Fracture uneven. H. = 4; G. = 2·93 to 3. Yellowish or reddish brown; streak pale green. Vitreous to resinous lustre. C.c.: silica 29·9, titanic acid 9·9, oxide of cerium metals 26·5, lime 19, water 8·9. Brevig and Langesundfiord.

673. Eudialite (*Eukolite*), $6\dot{R}\ddot{S}i_2 + \dot{R}\ddot{Z}r$.

Rhombohedral; R 73° 10′. R (*p*), 0R (a_1), ∞P2 (d_1), ¼R (a_2); also ∞R, ⅝R, $-\frac{1}{2}$R, -2R, $-\frac{1}{4}$R, R3, ⅔P2 (fig. 591). Generally massive, granular. Cl. a_1 and a_2; fracture uneven. H. = 5 to 5·5; G. = 2·81 to 2·95. Peachblossom-red to brownish red; streak white. Translucent; vitreous. B.B. fuses easily to a light-green opaque glass; gelatinizes in h. acid. C.c.: silica 50, zirconia 16·9, protoxide of iron 7, lime 11, soda 12. Kangerdluarsuk in Greenland, Sedlovatoi Island in White Sea, Brevig (*Eukolite*), Magnet Cove in Arkansas.

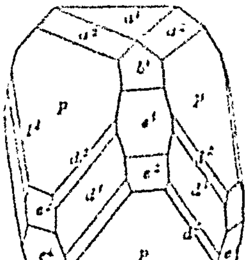


Fig. 591 (sp. 673).

674. Catapleite, $2(\dot{N}a_2\dot{C}a)(\ddot{S}i\ddot{Z}r)_3 + 9\dot{H}$.

Hexagonal. P 114° 43′. 0P, ∞P, P, also with 2P, and ½P. In lamellar aggregates. Cl. prismatic and P; fracture uneven. H. = 6; G. = 2·8. Yellowish brown to pale green; streak yellow, lustrous. C.c.: silica 46·7, zirconia 29·6, soda 10·8, water 9. Brevig.

675. Œrstedite.

Pyramidal. P 84° 25′. P, ∞P, ∞P∞. Like zircon. H. = 5·5; G. = 3·63. Lustre adamantine. Reddish brown. C.c.: silica 19·7, titanate of zirconia 68·96, water 5·6. Arendal.

676. Wöhlerite, $9\dot{R}\ddot{S}i + 3\dot{R}\ddot{Z}r + \dot{R}\ddot{\ddot{N}}b$.

Oblique prismatic, C 70° 45′. ∞P 90° 14′; ∞P∞2 127° 4′; $-$P∞ 43° 13′. 0P : ∞P∞ 109° 15; $-$P∞ : ∞P∞ 136° 42′; 0P : ∞P 103° 31′. Crystals tabular and prismatic. Cl. clinodiagonal; fracture conchoidal. H. = 5 to 6; G. = 3·4. Light yellow, honey-yellow to brownish grey; streak yellowish white. C.c.: silica 28, zirconia 19, niobic acid 13·9, lime 27·3, soda 8·3, protoxide of iron 3. B.B. fuses to yellowish glass. Sol. in h. acid. Langesundfiord, Brevig.

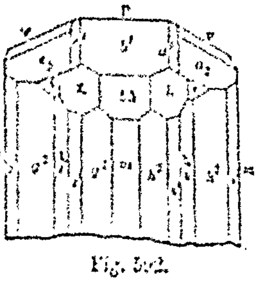


Fig. 592.

677. Ardennite.

Right prismatic. ∞P 131° 2′; P∞ 112° 23′; P⅓; ∞P⅓; ∞P2; ∞P∞; ∞P∞. Crystals like ilvanite. Cl. brachydiagonal, and ∞P. H. = 6 to 7; G. = 3·62. Yellow to yellow-brown. Dichroic; brittle. C.c.: silica 27·8, alumina 24, protoxide of manganese 26·7, lime 2·2, magnesia 1·3, vanadic acid 3·2, arsenic acid 6·3, water 5. Ottrez in the Ardennes (Luxemburg).

678. Roscoelite.

Foliated masses, sometimes stellated. H. = 1; G. = 2·3 to 2·9. Dark green to greenish blue. Pearly lustre. C.c.: silica 47·7, vanadic acid 22, alumina 14·1, magnesia 2, potash 7·6, water 5. Eldorado in California.

TITANATES WITH NIOBATES.

679. Titanomorphite, $\dot{C}a\ddot{T}i_2$.

Oblique prismatic. Like sphene. ∞P, 0P, ½P∞, P∞, ½P2. C.c.: titanic acid 74·3, lime 25·3. Lampersdorf in Silesia, Weistritz.

680. Perovskite, $\dot{C}a\ddot{T}i$.

Right prismatic. In complicated twins, often distorted, pseudo-cubic. H. = 5·5; G. = 4 to 4·1. Lustre metallic-adamantine. Pale yellow, reddish brown to iron-black; streak grey. C.c.: 58·8 titanic acid, 41·2 lime. B.B. with micro-salt in outer flame gives a bead greenish while hot, colourless on cooling; in inner flame grey-green when hot, violet-blue when cold. Decomposed by boiling s. acid. Zlatoust, Schelingen, Zermatt, Malenco Valley near Sondrio, Pfitsch in Tyrol, Magnet Cove in Arkansas.

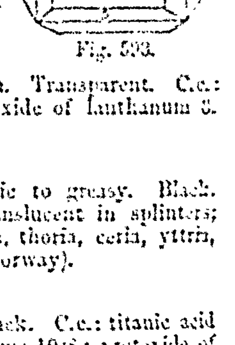


Fig. 593.

681. Koppite, $\dot{R}_2\ddot{\ddot{N}}b_2$.

Cubic; ∞O∞. G. = 4·45 to 4·56. Brown. Transparent. C.c.: niobic acid 62·46, oxide of cerium 6·7, oxide of lanthanum 3. Schelingen on the Kaiserstuhl in Baden.

682. Annerödite, $2\dot{R}_3\ddot{\ddot{N}}b + 5\dot{H}$:

Right prismatic. H = 6. G 5·7. Metallic to greasy. Black. Streak black, brown, greenish grey. Translucent in splinters; brittle. C.c.: 48 niobic acid, with zirconia, thoria, ceria, yttria, and uranium oxide. Annerod near Moss (Norway).

683. Dysanalyte, $6\dot{R}\ddot{T}i + \dot{R}\ddot{\ddot{N}}b$.

Cubic; ∞O∞. Cl. cubic. G. = 4·13. Black. C.c.: titanic acid 41·5, niobic acid 23·2, cerium oxide 5·7, lime 19·8; protoxide of iron 5·8, soda 3·0. Vogtsburg on the Kaiserstuhl.

684. Pyrochlore, $5\dot{R}\ddot{\ddot{N}}b + 1\dot{R}(\ddot{T}i\ddot{T}h)_2 + 4NaF$.

Cubic (fig. 594). Cl. octahedral; brittle; fracture conchoidal. H. = 5; G. = 4·2 to 4·4. Resinous, opaque. Red-brown to black, ruby-red and transparent rarely; streak pale brown. C.c.: niobic acid 53·2, titanic acid 10·5, thoria 7·6, cerium oxide 7, lime 14·2, soda 5, fluorine 3·1. Miask, Kaiserstuhl, Brevig, and Frederiksvärn. *Microlite*, from Chesterfield in Massachusetts, has tantalic acid 68·4, niobic acid 7·75, 11·7 lime and 7·7 protoxide of manganese. *Pyrrhite* from Mursinsk in the Urals, San Piero in Elba, and the Azores may be the same; at the last locality it is in orange-red octahedra, and is a niobate of zirconia.

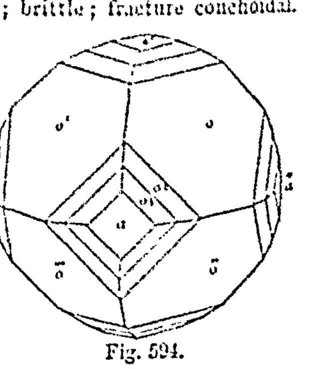


Fig. 594.

685. Blomstrandite, $(\dot{C}a, \dot{F}e), \ddot{T}i + \ddot{U}\ddot{\ddot{N}}b_3 + \dot{H}$.

Massive. H = 5·5. G. = 4·17 to 4·25. Vitreous, black. Streak

brown. Translucent in splinters. C.c.: niobic acid 49·8, titanic acid 10·7, uranium oxide 23·7, protoxide of iron 3·3, lime 3·5, water 7·9. Nohl (Sweden).

686. Polycrase, $4\ddot{R}\ddot{T}i + \dot{R}\dddot{N}b$.

Right prismatic (fig. 595). $\infty\breve{P}\infty$, ∞P (140°), P, $2\bar{P}\infty$ (56°). Fracture conchoidal. H. = 5 to 6; G. = 5·1. Black; streak grey-brown. B.B. decrepitates violently, incandescing, but does not fuse. Sol. in s. acid. C.c.: titanic acid 26·6, niobic acid 20·4, yttria 23·3, erbia 7·5, oxide of uranium 7·7, water 4. Hitterö (Norway), Slettåkra in Jönköping (Sweden).

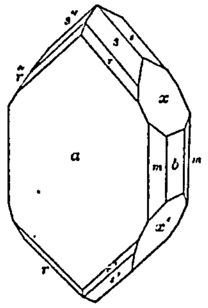


Fig. 595.

687. Euxenite, $2\ddot{R}\ddot{T}i + \dot{R}\dddot{N}b + \dot{H}$.

Right prismatic (fig. 596). ∞P (m) 140°; $\infty\breve{P}\infty$ (b); $2\bar{P}\infty$ (d) 52°; P (p) 102° 58′. $p : b$ 103° 6′. Fracture conchoidal. Opaque; metallic to vitreous. Black and brownish black; streak red-brown. B.B. infusible. Not acted on by acids. C.c.: niobic acid 32, titanic acid 19·2, uranium oxide 19·5, yttria 18·2, cerium oxide 2·8, but variable. Jölster, Tromö, Alvö, &c., in Norway; also Hitterö and Cape Lindesnaes.

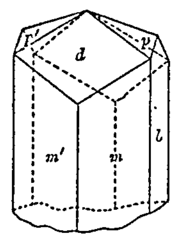


Fig. 596.

688. Æschynite.

Right prismatic. ∞P (M) 128° 34′; $2\breve{P}\infty$ (y) 73° 16′; P ($o : o$) 137° 14′; $\infty P3$ 69° 23′; $\bar{P}\infty$; 0P. Crystals long prismatic (fig. 597). Cl. traces; fracture imperfect conchoidal. H. = 5 to 5·5; G. = 4·9 to 5·1. Opaque; submetallic or resinous. Iron-black or brown; streak yellowish brown. B.B. swells and becomes yellow or brown, but is infusible. Not sol. in h. acid, partially in s. acid. C.c.: niobic and tantalic acids 28·8, titanic acid 22·6, thorium oxide 15·7, cerium protoxide 18·5, lanthanum oxide and didymium oxide 5·6. Miask, Hitterö.

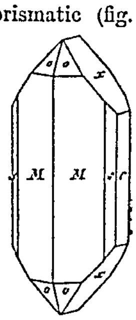


Fig. 597 (sp. 688).

689. Polymignite.

Right prismatic. P (p) polar 136° 28′ and 116° 22′; ∞P 109° 46′; $\infty\bar{P}\infty$; $\infty\breve{P}\infty$ (fig. 598). Cl. macro- and brachydiagonal, imperfect; fracture conchoidal. H. = 6·5; G. = 4·7 to 4·8. Opaque; semimetallic. Iron-black; streak dark brown. B.B. infusible. Sol. in h. acid. C.c.: titanic acid 46·3, zirconia 14·1, yttria 11·5, lime 4·1, iron peroxide 12·2, cerium oxide 5. Frederiksvärn.

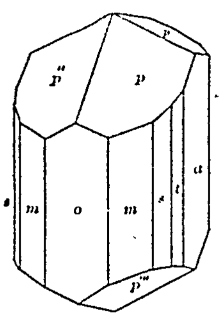


Fig. 598 (sp. 689).

690. Mengite, ($\dddot{F}e$, $\ddot{Z}r$) $\ddot{T}i$.

Right prismatic. P (e) polar angle 151° 27′ and 101° 10′; ∞P 136° 20′; $\infty\breve{P}3$; $\infty P\infty$ (fig. 599). Fracture uneven. H. = 5 to 5·5; G. = 5·48. Opaque; semimetallic. Iron-black; streak chestnut-brown. B.B. infusible, but becomes magnetic. Sol. in s. acid. Miask, Groix island in Morbihan.

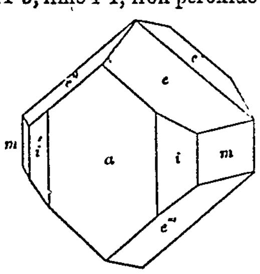


Fig. 599 (sp. 690).

691. Tantalite, $\dot{F}e$ ($\dddot{T}a$, $\dddot{N}b$).

Right prismatic. P (p) with polar edges 126° and 112° 30′, middle 91° 42′. $\infty\breve{P}\frac{4}{3}$ (r) 122° 53 $\infty\bar{P}\infty$ (s); $\infty\breve{P}\infty$ (t); $\breve{P}\infty$ (m) 113° 48; $3\breve{P}\infty$ (q) 54° 10′; $\frac{1}{6}\breve{P}\infty$ (n) 167° 36′; $\frac{4}{3}\breve{P}\frac{4}{3}$ (v); $2\breve{P}2$ (o). Fracture conchoidal or uneven. H. = 6 to 6·5; G. = 6·1 to 8. Opaque; semimetallic, adamantine, or resinous. Iron-black; streak cinnamon- or coffee-brown. B.B. infusible; scarcely affected by acids. C.c.: 76 to 50 tantalic acid, 7·5 to 29 niobic acid, 9 to 16 iron protoxide, and 1 to 6 manganese protoxide; some with 1 to 10 tin oxide (*Cassiterotantalite*); also in union with iron (manganese) protoxide. Kimito and Tammela in Finland, Broddbo and Finbo near Falun, and Chanteloube near Limoges; always in granite.

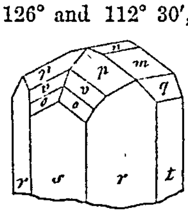


Fig. 600.

692. Tapiolite, $4\dot{F}e\dddot{T}a + \dot{F}e\dddot{N}b$.

Pyramidal. P middle angle 84° 52′, summit 123° 1′. H. = 6; G. = 7·2 to 7·5. Black. Lustrous. C.c.: tantalic acid 73·9, niobic acid 11·2, protoxide of iron 15. Tammela in Finland.

693. Columbite, $m\dot{F}e\dddot{N}b + n\dot{F}e\dddot{T}a$.

Right prismatic. P (u) polar angles 104° 10′ and 151°, middle angle 83° 8′; 0P (c); $\infty\breve{P}\infty$ (b); $\infty\bar{P}\infty$ (a); ∞P (g) 135° 40′; $\infty\breve{P}\infty$ (m) 101° 26′; 2P (s); $3\breve{P}3$ (o); $3\breve{P}\frac{3}{2}$ (π); $\frac{1}{2}\breve{P}\infty$ (l) 161°; $\breve{P}\infty$ (k) 143°; $2\breve{P}\infty$ (h) 112° 26′; $\bar{P}\infty$ (i) 101° 12′; $2\bar{P}\infty$ (e) 62° 40′. Hemitropes, face e; vertical axes forming an angle of 62° 40′; also on faces 2P2 (n), and rarely b. Also granular and foliated. Cl. brachydiagonal, perfect, also macrodiagonal. H. = 6; G. = 5·4 to 6·4. Metallic, adamantine. Iron-black to brownish; streak black or reddish brown. B.B. infusible; not affected by acids. C.c.: isomorphic mixtures of niobic and tantalic acids with protoxide of iron (or manganese). Pure columbite would give 78·8 niobic acid, pure tantalite 86 tantalic acid. The niobic acid generally prevails, and the crystals are better formed the more this is the case. Rabenstein, Bodenmais, Chanteloube, Finland, Ilmen Hills, Evigtok in Greenland, Haddam and Middletown in Connecticut, Acworth in New Hampshire, Pike's Peak in Colorado.

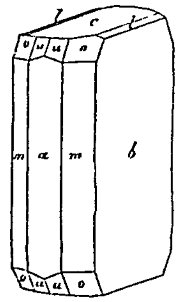


Fig. 601.

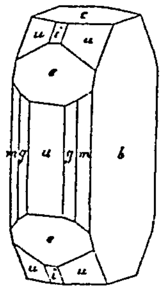


Fig. 602.

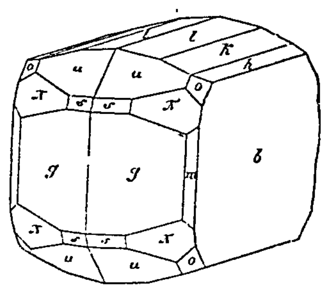


Fig. 603.

694. Yttrotantalite, ($\dot{Y}$, $\dot{C}a$, $\dot{F}e$, $\dot{U}$)$_2$($\dddot{T}a$, $\dddot{W}$, $\dddot{N}b$).

In two varieties. (*a*) *Black*. Right prismatic; in short prismatic or tabular crystals. $\infty\breve{P}\infty$; ∞P (m) 121° 48′. 0P : $2\breve{P}\infty$ 103° 26′; $\breve{P}\infty$: 0P 131° 26′; $i : i$ 149° 42′ (fig. 604); also in grains and lamellæ. Cl. brachydiagonal, indistinct; fracture conchoidal or uneven. Opaque, or in thin splinters translucent. Velvet-black, semimetallic lustre, and greenish grey streak. H. = 5·5; G. = 5·4 to 5·7. (*b*) *Yellow*. Amorphous, yellowish brown, or yellow, often striped or spotted; resinous or vitreous; streak white. G. = 5·46 to 5·88. Both varieties B.B. infusible, but become brown or yellow. Not affected by acids. C.c.: 57 to 60 tantalic acid, 1 to 8 tungstic acid, 0 to 20 niobic acid, 20 to 38 yttria, 0·5 to 6 lime, 0·5 to 6 uranium peroxide, and 0·5 to 3·5 iron peroxide. Ytterby, and near Falun.

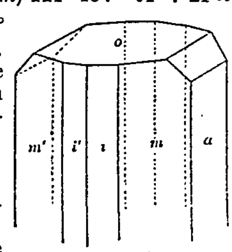


Fig. 604.

695. Fergusonite, ($\dot{Y}$, $\dot{E}r$, $\dot{C}e$)$_3$($\dddot{N}b$, $\dddot{T}a$).

Pyramidal and hemihedric; P (s) 128° 28′. Usual form ($\frac{1}{2}$) $3P\frac{3}{2}$ (z), P, $\frac{1}{2}\infty P\frac{3}{2}$ (g), 0P (c) (fig. 605). $s : s$ 100° 54′, $s : c$ 115° 16′, $z : r$ 169° 17. Cl. traces along P; fracture imperfect conchoidal; brittle. H. = 5·5 to 6; G. = 5·6 to 5·9. Translucent in thin splinters; semimetallic. Brownish black; streak pale brown. B.B. infusible. C.c.: chiefly niobic acid and yttria, with erbia, also a little cerium protoxide, tin oxide, uranium oxide, and iron protoxide. Cape Farewell in Greenland, Ytterby, Riesengebirge, Rockport in Massachusetts. *Tyrite*, from Helle near Arendal, is similar.

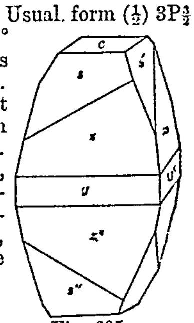


Fig. 605.

696. Hjelmite.

Massive, with granular fracture and traces of crystals. H. = 5; G. = 5·82. Velvet-black; streak greyish black. Lustre metallic. C.c.: tantalic acid 62·4, tin 6·6, uranium 4·9, protoxide of iron 8·1, yttria 5·2. B.B. infusible. In closed tube decrepitates and yields water. Kararfvet near Falun.

697. Samarskite (*Uranotantalite*), ($\dot{R}_3$, $\dddot{R}$, $\ddot{R}\frac{3}{2}$)$_5$($\dddot{N}b\dddot{T}a$)$_3$.

Right prismatic. ∞P 122° 46′; $\infty\breve{P}2$ 95°; $\bar{P}\infty$ 93°; P; $\infty\bar{P}\infty$; $\infty\breve{P}\infty$; $3\breve{P}\frac{3}{2}$; also in grains. Fracture conchoidal; brittle. H. = 5·56; G. = 5·6 to 5·76. Opaque; strong semimetallic. Velvet-black; streak dark reddish brown. B.B. fuses on the edges to a black glass. In the closed tube decrepitates, yields water, incandesces, and becomes brown. Sol. in h. acid to a greenish fluid.

C.c.: 37·2 niobic acid, 18·6 tantalic acid, 12 iron protoxide, 14 to 20 uranium oxide, 6 thorium oxide, 4 zirconia, and 16 yttria with lime and magnesia. Miask, Mitchell county in North Carolina. The *Yttroilmenite* of Hermann.

698. NOHLITE, $\dot{\mathrm{R}}_3\ddot{\ddot{\mathrm{N}}}\mathrm{b}$.

Massive. H=4·5 to 5; G.=5·04. Black-brown. Splintery. Brittle. Opaque; vitreous. Niobic acid 50·4, uranium oxide 14·4, zirconia 3, ferrous oxide 8, yttria 14·4, lime 4·7, water 4·6. Nohl near Kongelf (Sweden).

699. HATCHETTOLITE.

Cubic; O, ∞O∞. Yellowish brown. Resinous lustre. Fracture conchoidal. H.=5; G.=4·8 to 4·9. C.c.: niobic acid 34·3, tantalic acid 29·8, uranium oxide 15·5, lime 8·9, water 4·5. North Carolina.

ANTIMONIATES.

700. ROMEITE, $\dot{\mathrm{C}}\mathrm{a}_3\dddot{\mathrm{S}}\mathrm{b}\ddot{\ddot{\mathrm{S}}}\mathrm{b}$.

Pyramidal; P 110° 50′. Scratches glass. G.=4·7. Honey-yellow or hyacinth-red. B.B. fuses to a blackish slag. Sol. in acids. C.c.: 41·3 antimonic acid, 37·3 antimony oxide, and 21·4 lime, but with 2 to 3 manganese and iron protoxide. St Marcel in Piedmont. *Schneebergite*, from Tyrol, may be an impure variety.

701. BLEINIERE, $\dot{\mathrm{P}}\mathrm{b}(\dddot{\mathrm{S}}\mathrm{b}, \ddot{\ddot{\mathrm{S}}}\mathrm{b})+\dot{\mathrm{H}}$.

Reniform and massive. H.=4; G.=3·9 to 4·8. Translucent; resinous to earthy. Colourless, yellow, brown, and grey. B.B. reduced on charcoal. C.c.: oxide of lead 41 to 62, antimonious acid 32 to 47, water 6 to 12. Lostwithiel, Horhausen, Nertchinsk.

702. NADORITE, $\dot{\mathrm{P}}\mathrm{b}\dddot{\mathrm{S}}\mathrm{b}+\mathrm{PbCl}_2$.

Right prismatic; ∞P 132° 51′. Crystals tabular. Cl. macrodiagonal. H.=3; G.=7. Yellowish or greyish brown. Resinous to adamantine; translucent. C.c.: lead 52·2, antimony 30·8, oxygen 8, chlorine 9. Constantine (Algeria).

703. RIVOTITE.

Massive. Yellowish to greyish green. Opaque; fracture uneven; brittle. H.=3·5 to 4; G.=3·6. C.c.: oxide of copper 39·5, oxide of silver 1·2, antimonic acid 42, carbonic acid 21. Sierra del Cadi in the province of Lerida. *Thrombolite* from Rezbanya, Hungary, may be a hydrated variety.

704. MELLITE, $\dddot{\mathrm{A}}\mathrm{l}(\mathrm{C}_{12}\mathrm{O}_9)+18\dot{\mathrm{H}}$.

Pyramidal; P 93° 5′. 0P; P∞; and ∞P∞. Cl. P; fracture conchoidal; brittle. H.=2 to 2·5; G.=1·5 to 1·6. Transparent; doubly refractive; vitreous. Honey-yellow or reddish; streak white. In closed tube yields water. B.B. chars without odour. Burns white and acts like alumina. Sol. in n. acid or potash. C.c.: alumina 14·4, mellic acid 40·3, water 45·3. In lignite at Artern in Thuringia and Luschitz in Bohemia; Walchow in Moravia (cretaceous); in coal at Malovka in Tula.

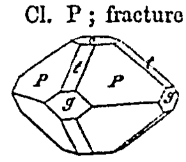


Fig. 606.

705. OXALITE, $2\dot{\mathrm{F}}\mathrm{e}\bar{\mathrm{C}}_3+3\dot{\mathrm{H}}$.

Capillary crystals, also botryoidal or compact; fracture uneven; sectile. H.=2; G.=2·2. Opaque; resinous to dull. Straw-yellow. B.B. turns black, then red. Sol. to yellow solution in acids. C.c.: 42·1 iron protoxide, 42·1 oxalic acid, 15·8 water. In lignite at Kolosoruk near Bilin, Duisburg, and Gross Almerode in Hesse.

706. WHEWELLITE, $\dot{\mathrm{C}}\mathrm{a}\bar{\mathrm{C}}+\dot{\mathrm{H}}$.

Oblique prismatic, C 72° 41′. ∞P 100° 36′. Cl. basal, perfect; brittle. H.=2·5 to 2·8; G.=1·838. Transparent to opaque; vitreous. Colourless. C.c.: 49·31 oxalic acid, 38·36 lime, 12·33 water. Hungary.

THE MINERAL RESINS.

Many of these are only vegetable resins slightly altered. Naphtha is fluid; the others solid, with H.=1 to 2 or 2·5. Most are amorphous, a few crystalline and monoclinic. G.=0·6 to 1·6. Mostly resinous; colourless, or coloured brown, yellow, or red, with paler streak. Sol. in acids, alcohol, ether, and oils. Melt readily, and burn with flame and smoke.

707. NAPHTHA, PETROLEUM, CH_2.

Liquid. Colourless, yellow, or brown. Transparent or translucent. G.=0·7 to 0·9. Volatilizes in the atmosphere with an aromatic bituminous odour. C.c.: 84 to 88 carbon, and 12 to 16 hydrogen. Varieties are—

Naphtha.—Very fluid, transparent, and light yellow. Tegern Lake in Bavaria, Amiano near Parma, Salies in the Pyrenees, Rangoon, Baku on the Caspian Sea, China, Persia, and North America. Used for burning, and in preparing varnishes.

Petroleum.—Darker yellow or blackish brown; less fluid or volatile. Ormskirk in Lancashire; Coalbrookdale, Pitchford, and Madeley in Shropshire; St Catherine's Well, south of Edinburgh; Mainland of Orkney; and many other parts of Europe.

708. ELATERITE (*Elastic Bitumen, Mineral Caoutchouc*), CH_2.

Compact; reniform or fungoid; elastic and flexible like caoutchouc, very soft. G.=0·8 to 1·23. Resinous. Blackish, reddish, or yellowish brown. Strong bituminous odour. C.c.: 84 to 86 carbon, 12 to 14 hydrogen, and a little oxygen. Derbyshire, Montrelais near Nantes, and Woodbury in Connecticut.

709. ASPHALTUM, BITUMEN.

Compact and disseminated; fracture conchoidal, sometimes vesicular; sectile. H.=2; G.=1·1 to 1·2. Opaque, resinous, and pitch-black; strong bituminous odour, especially when rubbed. Takes fire easily, and burns with a bright flame and thick smoke. Sol. in ether, except a small remainder, which is dissolved in oil of turpentine. C.c.: 76 to 88 carbon, 2 to 10 oxygen, 6 to 10 hydrogen, and 1 to 3 nitrogen. Limmer near Hanover, Seyssel on the Rhone, Val Travers in Neufchatel, Lobsann in Alsace, in the Harz, Dead Sea, Persia, and Trinidad; Cornwall, Haughmond Hill (Shropshire), East and West Lothians, Elie and Burntisland (Fife).

710. ALBERTITE.

Massive. Velvet-black. Adamantine lustre; brittle. C.c.: carbon 86, hydrogen 9, nitrogen 2·9, oxygen 2. Hoy, Orkney; Strathpeffer, Ross; Hillsborough, New Brunswick.

711. PIAUZITE.

Massive; imperfect conchoidal, sectile. H.=1·5; G.=1·22. Dimly translucent on very thin edges; resinous. Blackish brown; streak yellowish brown. Fuses at 600° Fahr., and burns with an aromatic odour, lively flame, and dense smoke. Sol. in ether and caustic potash. Piauze near Rudolfswerth in Carniola.

712. IXOLYTE.

Massive; conchoidal fracture. H.=7; G.=1·008. Resinous. Hyacinth-red; streak ochre-yellow. Rubbed between the fingers it emits an aromatic odour; becomes soft at 119°, but is still viscid at 212°. Oberhart near Gloggnitz in Austria.

713. AMBER (*Succinite*), $\mathrm{C}_{10}\mathrm{H}_8\mathrm{O}$.

Round irregular lumps, grains, or drops. Fracture perfect conchoidal; slightly brittle. H.=2 to 2·5; G.=1 to 1·1. Transparent to translucent or almost opaque; resinous. Honey-yellow, hyacinth-red, brown, yellowish white; also streaked or spotted. When rubbed emits an agreeable odour, and becomes negatively electric. It melts at 550°, emitting water, an empyreumatic oil, and succinic acid; it burns with a bright flame and pleasant odour, leaving a carbonaceous remainder; only a small part is soluble in alcohol. C.c.: 79 carbon, 10·5 hydrogen, and 10·5 oxygen. Derived chiefly from an extinct coniferous tree (*Pinites succinifer*), and found in the Tertiary and diluvial formations of many countries, especially northern Germany and shores of the Baltic, Sicily, Spain, and northern Italy, rarely in Britain (on the shores of Fife, Norfolk, Suffolk, and Essex, and at Kensington, near London). Used for ornamental purposes, and for preparing succinic acid and varnishes. *Krantzite*, from Nienburg, is essentially the same.

714. RETINITE (*Retinasphalt*).

Roundish or irregular lumps; fracture uneven or conchoidal; very easily frangible. H.=1·5 to 2; G.=1·05 to 1·15. Translucent or opaque; resinous or glistening. Yellow or brown. Melts at a low heat, and burns with an aromatic or bituminous odour. C.c.: in general carbon, hydrogen, and oxygen, in very uncertain amount. Bovey, Halle, Cape Sable, and Osnabrück. *Pyroretinite* from Aussig in Bohemia is similar.

715. WALCHOWITE, $\mathrm{C}_{12}\mathrm{H}_9\mathrm{O}$.

Rounded pieces, with a conchoidal fracture. H.=1·5 to 2; G.=1·035 to 1·069. Translucent, resinous. Yellow with brown stripes, and a yellowish white streak. It fuses at 482°, and burns readily. Soluble partially (7·5 per cent.) in ether; in s. acid forms a dark-brown solution. C.c.: 80·4 carbon, 10·7 hydrogen, and 8·9 oxygen. Walchow in Moravia.

716. COPALINE (*Fossil Copal, Highgate Resin*), $\mathrm{C}_{40}\mathrm{H}_{64}\mathrm{O}$.

Irregular fragments. H.=1·5; G.=1·046. Translucent, resinous; burns with light yellow flame and much smoke; alcohol dissolves little of it; becomes black in sulphuric acid. C.c.: 85·54 carbon, 11·63 hydrogen, 2·76 oxygen. Highgate near London. A similar resin from Settling-Stones mine in Northumberland, found in flat drops or crusts on calc-spar, is infusible at 500° Fahr.; G.=1·16 to 1·54; it contains 85·13 carbon, 10·85 hydrogen, and 3·26 ashes.

717. BERENGELITE, $\mathrm{C}_{40}\mathrm{H}_{62}\mathrm{O}_8$.

Amorphous; conchoidal fracture. Dark brown, inclining to green; yellow streak. Resinous; unpleasant odour, and bitter taste. Fuses below 212°, and continues soft afterwards at ordinary temperatures; easily soluble in alcohol. C.c.: 72·40 carbon, 9·28 hydrogen, 18·31 oxygen. San Juan de Berengela in Peru.

718. GUAYAQUILLITE, $\mathrm{C}_{20}\mathrm{H}_{26}\mathrm{O}_3$.

Amorphous; yielding easily to the knife, and very friable. G.

=1·092. Pale yellow. Slightly resinous. Fluid at 212°, viscid when cold; slightly soluble in water, and largely in alcohol, forming a yellow fluid with a bitter taste. C.c.: 77·01 carbon, 8·18 hydrogen, and 14·80 oxygen. Guayaquil in South America.

Bogbutter, from the Irish peat mosses, is similar; it melts at 124°, is easily soluble in alcohol, and contains 73·70 carbon, 12·50 hydrogen, and 13·72 oxygen.

719. HARTINE, $C_{20}H_{20}+\dot{H}$.

Round masses or thin layers. Brittle, but easily cut with a knife. G.=1·6. Resinous. Reddish brown by reflected and deep red by transmitted light; streak light brown. Becomes black on exposure. C.c.: 86·43 carbon, 8·01 hydrogen, 5·56 oxygen. In the main coal seam at Middleton near Leeds, and at Newcastle.

720. OZOCERITE (*Native Paraffin*), CH.

Amorphous, sometimes fibrous. Very soft, pliable, and easily fashioned with the fingers. G.=0·94 to 0·97. Glimmering or glistening; semitranslucent. Yellowish brown or hyacinth-red by transmitted, dark leek-green by reflected light. Strong paraffin or aromatic odour; fuses easily to a clear oily fluid; at higher temperature burns with a clear flame, seldom leaving any ashes; readily soluble in oil of turpentine, with great difficulty in alcohol or ether. C.c.: 85·7 carbon, and 14·3 hydrogen. Binny (Linlithgow), and Edinburgh; Slanik and Zietriska in Moldavia, near Garning in Austria, and Baku; also at Urpeth coal-mine near Newcastle-on-Tyne. *Pyropissite* may be a variety.

721. HATCHETTINE (*Mineral Tallow*).

Flaky, like spermaceti; or subgranular, like beeswax; soft and flexible. G.=0·6. Translucent; weak pearly. Yellowish white, wax-yellow, or greenish yellow. Greasy inodorous; readily soluble in ether. C.c.: 85·91 carbon, 14·62 hydrogen, or similar to ozocerite. Loch Fyne (fusible at 115°), Merthyr-Tydvil, Schaumburg.

722. FICHTELITE, C_4H_3.

Crystalline (oblique prismatic) lamellæ, which swim in water, but sink in alcohol. White and pearly. Fuse at 114°, but again become crystalline on cooling. Very easily soluble in ether, and precipitated by alcohol. C.c.: 88·9 carbon and 11·1 hydrogen. In pine wood in a peat-moss near Redwitz in Bavaria.

723. HARTITE, C_6H_5.

Anorthic; but mostly like spermaceti or white wax, and lamellar. Sectile, but not flexible. H.=1; G.=1·046. Translucent; dull resinous. White. Melts at 165°, and burns with much smoke. Very soluble in ether, much less so in alcohol. C.c.: 87·8 carbon, and 12·2 hydrogen. Oberhart in Austria.

724. KÖNLITE, C_2H.

Crystalline folia and grains. Soft. G.=0·88. Translucent; resinous. White, without smell. Fuses at 120° to 137°. Sol. in n. acid; precipitated by water in a white crystalline mass. C.c.: 92·3 carbon, 7·7 hydrogen. Uznach near St Gall, Redwitz.

725. SCHEERERITE, CH_2.

Oblique prismatic; tabular or acicular. Soft and rather brittle. G.=1 to 1·2. Translucent; resinous or adamantine. White, inclining to yellow or green. Feels greasy, has no taste, and when cold no smell, but when heated a weak aromatic odour. Insoluble in water; readily sol. in alcohol, ether, and n. and s. acids. C.c.: 75 carbon, 25 hydrogen. Uznach. *Branchite*, white, translucent, fusing at 167°, is similar; Montevaso in Tuscany.

726. IDRIALITE, C_3H_2.

Massive; fracture uneven or slaty; sectile. H.=1 to 1·5; G.=1·4 to 1·6 (1·7 to 3·2). Opaque; resinous. Greyish or brownish black; streak blackish brown, inclining to red. Feels greasy. Burns with a thick smoky flame, giving out sulphurous acid, and leaving some reddish brown ashes. C.c.: 77 idrialine (=94·7 carbon and 5·3 hydrogen) and 18 cinnabar, with a little silica, alumina, pyrite, and lime. The idrialine may be extracted by warm olive oil or oil of turpentine as a pearly shining mass, difficultly fusible. Idria.

727. TORBANITE.

Massive; fracture subconchoidal. Yellow, brown-grey, and light brown. H.=1·5 to 2; G.=1·28. C.c.: 60 to 65 carbon, 9 hydrogen, 4 to 5 oxygen, 10 to 20 silicate of alumina. When distilled below redness yields a burning fluid holding paraffin in solution; above redness a large quantity of highly illuminating gas. Shown by the microscope to consist of granules of a yellow bituminoid wax, with interstitial shaly matter. Torbanehill in Scotland, Pilsen in Bohemia, Kurakina and Murayevna in Russia.

728. DOPPLERITE.

Jelly-like elastic masses. Brownish black; streak brown. Greasy lustre. H.=0·5; G.=1·1. After drying H.=2·5; G.=1·5. Insoluble in alcohol and ether. An acid substance related to humic acid. From peat beds, Aussee (Styria) and Switzerland.

THE COALS.

729. ANTHRACITE (*Glance Coal*).

Massive and disseminated; rarely columnar. Fracture conchoidal; brittle. H.=2 to 2·5; G.=1·4 to 1·7. Opaque; brilliant metallic. Iron-black; streak unaltered. Perfect conductor of electricity. Burns difficultly with a very weak or no flame, and does not cake; in the closed tube yields a little moisture, but no empyreumatic oil; detonates with nitre. C.c.: carbon above 90 per cent., with 1 to 3 oxygen, 1 to 4 hydrogen, and 0 to 3 nitrogen; and ashes chiefly of silica, alumina, lime, and peroxide of iron. Common in some parts of all coal-fields; and especially in the United States, as in Rhode Island, Massachusetts, and above all in Pennsylvania. Used chiefly for manufacturing metals.

730. COMMON COAL (*Black Coal, Stone or Mineral Coal, Bituminous Coal*).

Compact, slaty, or confusedly fibrous; often dividing into rhomboidal, columnar, or cubical fragments. Fracture conchoidal, uneven, or fibrous; rather brittle or sectile. H.=2 to 2·5; G.=1·2 to 1·5. Vitreous, resinous, or silky in the fibrous variety. Blackish brown, pitch-black, or velvet-black. Burns easily, emitting flame and smoke, with a bituminous odour; heated in the closed tube yields much oil. C.c.: 74 to 90 carbon, with 0·6 to 8 or 15 oxygen, 3 to 6 hydrogen, 0 to 1 to 2 nitrogen, 0·1 to 3 sulphur, and 1 to 11 earthy matters or ash, in 100 parts.

Slate Coal or *Splint* has a thick slaty structure, and an uneven fracture. *Cherry Coal* is the name applied to the brittle highly lustrous variety common in the English coal-fields. *Caking Coal* is a more bituminous variety which undergoes semifusion when ignited, caking or agglutinating during combustion. *Cannel Coal* has a resinous, glimmering lustre, and a flat-conchoidal fracture, breaks into irregular cubical fragments, but is more solid and takes a higher polish than other varieties. This burns with a bright flame, and yields much gas. Abundant in many lands, as in England, Scotland, and Ireland, in Belgium and France, in Germany and southern Russia. British America and the United States possess immense fields, especially in the valley of the Mississippi. Also found in China, Japan, Hindustan, Australia, Borneo, and several of the Indian islands.

731. LIGNITE (*Jet, Brown Coal*).

Distinctly vegetable in origin,—the external form, and very often the internal woody structure, being preserved. The texture is compact, woody, or earthy. Fracture conchoidal, woody, or uneven; soft and often friable. G.=0·5 to 1·5. Lustre sometimes resinous, mostly glimmering or dull. Brown, black, or rarely grey. Burns easily with an unpleasant odour; colours solution of potash deep brown. C.c.: 47 to 73 carbon, 2·5 to 7·5 hydrogen, 8 to 33 oxygen (with nitrogen), and 1 to 15 ashes. *Jet* is pitch-black, with conchoidal fracture and resinous lustre. Brown coal occurs at Bovey-Tracy in Devonshire; also in Germany, Hungary, France, Italy, and Greece. The *Surturbrand* of Iceland seems a variety. Used as fuel, but much inferior to common coal. The Oolitic coals of Yorkshire, Antrim, Brora, Mull, and Skye are intermediate varieties.

INDEX OF MINERAL SPECIES.

(M. F. H.)

MINERAL WATERS. No absolute line of demarcation can be drawn between ordinary and mineral waters. There is usually in the latter an excess of mineral constituents or of temperature, but some drinking waters contain more mineral constituents than others that are called mineral waters, and many very pure waters, both cold and warm, have been regarded for ages as mineral springs.

As to the origin of mineral waters, there is much in what the elder Pliny said, that waters are such as the soil through which they flow. Thus in limestone and chalk districts an excess of lime is usually present; and the waters of a particular district have much resemblance to each other—as in the Eifel, in Auvergne, and in the Pyrenees. But this is only a partial explanation, for waters are by no means necessarily uniform throughout a particular geological formation. We do not know with any certainty the depth from which various mineral waters proceed, nor the various distances from the surface at which they take up their different mineral constituents.

The source of the temperature of thermal waters remains a subject of much uncertainty. Among the assigned causes are the internal heat of the globe, or the development of heat by chemical or electrical agencies in the strata through which they arise.

Their occasional intermittence is doubtless often dependent on the periodical generation of steam, as in the case of the Geysers. A few geological facts are certain, which bear on the origin of mineral waters. Such springs are most abundant in volcanic districts, where many salts of soda and much carbonic acid are present. They occur most frequently at meetings of stratified with unstratified rocks, in saddles, and at points where there has been dislocation of strata.

The diffusion of mineral waters is very extended. Pliny was quite correct in observing that they are to be found on alpine heights and arising from the bottom of the ocean. They are found at the snow in the Himalayas and they rise from the sea at Baiæ and Ischia. They are to be found in all quarters of the globe, but more particularly in volcanic regions, as in the Eifel and Auvergne, in the Bay of Naples, and parts of Greece, in Iceland, New Zealand, and Japan. But there are few countries in which they are not to be found, except in very flat ones and in deltas of rivers,—for instance, in the north of France, where they are very few, and in Holland, from which they are absent. France, Germany, Italy, and Spain, as well as Greece, Asia Minor, and the Caucasus, are all rich in mineral waters. The British Isles have a fair though not very large proportion of them. There are a few in Sweden and Norway. They are abundant in the United States, less so in Canada. They are found in the Azores and in the West India Islands. Of their occurrence in the interior of Africa or of Australia we know little; and the same is true of South America. But they are met with in Algiers, in Egypt, and in the Holy Land. The vast Indian peninsula has for its size a comparatively small supply.

As the effects of mineral waters on the bodily system have been found to be different from those of drinking waters, an explanation of this has been naturally sought for. It has been imagined that there is something special in the nature of mineral waters, that their heat is not ordinary heat, that their condition is a peculiar electric one. Some French modern writers even say that they have a certain life in them, that their constitution is analogous to that of the serum of the blood. But we must pass by these speculations, and be guided as far as possible by ascertained facts, respecting the action on the system of water, of heat and cold, and of the mineral constituents present.

Mineral waters, when analysed, are found to contain a great many substances, although some of them occur only in very minute quantities:—soda, magnesia, calcium, potash, alumina, iron, boron, iodine, bromine, arsenic, lithium, cæsium, rubidium, fluorine, barium, copper, zinc, manganese, strontium, silica, phosphorus, besides extractive matters, and various organic deposits known under the name of glairin or baregin. Of gases, there have been found carbonic acid, hydrosulphuric acid, nitrogen, hydrogen, oxygen, and ammonia. Of all these by far the most important in a therapeutic point of view are sodium, magnesia, and iron, carbonic acid, sulphur, and perhaps hydrosulphuric acid. These substances, detected separately by chemists, are in their analyses combined by them into various salts, if not with absolute certainty, undoubtedly

with a close approximation to it. Those combinations are very numerous, and some waters contain ten to twenty of them; but there are always some predominating ones, which mark their character, while many of them, such as cæsium, rubidium, or fluorine, occur in mere traces, and can not be assumed to be of any real importance. Mineral waters therefore resolve themselves into weaker or stronger solutions of salts and gases in water of higher or lower temperature. For medical purposes they are used either externally or internally, for bathing or for drinking. As the quantity of salts present commonly bears but a very small proportion to that of the fluid containing them, water becomes a very influential agent in mineral-water treatment, about which it is therefore necessary to say something.

For the action of hot and cold baths the reader is referred to the article BATHS. But it may be observed here that, according to the most generally received opinion, the cutaneous surface does not absorb any portion of the salts in a mineral-water bath, although it may absorb a little gas (an alkaline water, for instance, at most acting as a slight detergent on the skin), and that neither salts nor gases have any action on the system, except as stimulants of the skin, with partial action on the respiratory organs.

It seems to be ascertained that drinking considerable amounts of cold water reduces the temperature of the body, diminishes the frequency of the pulse, and increases the blood pressure temporarily. Water when introduced into the stomach, especially if it be empty, is quickly absorbed; but, although much of the water passes into the veins, there is no proof that it ever produces in them, as is sometimes supposed, a state of fluidity or wateriness. Therapeutically, the imbibition of large quantities of water leads to a sort of general washing out of the organs. This produces a temporary increase of certain excretions, augmented diuresis, and a quantitative increase of urea, of chloride of sodium, and of phosphoric and sulphuric acids in the urine. Both the sensible and the insensible perspirations are augmented. A draught of cold water undoubtedly stimulates the peristaltic action of the intestines. On the whole water slightly warm is best borne by the stomach, and is more easily absorbed by it than cold water; and warm waters are more useful than cold ones when there is much gastric irritability.

In addition to the therapeutic action of mineral waters, there are certain very important subsidiary considerations which must not be overlooked. An individual who goes from home to drink them finds himself in a different climate, with possibly a considerable change in altitude. His diet is necessarily altered, and his usual home drinks are given up. There is change in the hours of going to bed and of rising. He is relieved from the routine of usual duties, and thrown into new and probably cheerful society. He takes more exercise than when at home, and is more in the open air, and this probably at the best season of the year. So important has this matter of season and climate been found that it is an established axiom that waters can be used to the greatest advantage during the summer months and in fine weather, and during the periods most convenient for relaxation from business. Summer is therefore the bath season, but of late years provision has been made in many places, with the aid of specially constructed rooms and passages, for carrying out cures satisfactorily during the winter season, *e.g.*, at Aix-la-Chapelle, Wiesbaden, Baden Baden, Baden in Switzerland, Dax, Vichy, and Bath. The ordinary bath season extends from the 15th of May to the 20th or 30th September. The season for baths situated at considerable elevations commences a month later and terminates some ten days earlier. Mineral waters may be employed at home, but patients seldom so use them; and this necessarily limits the time of their use. It is common to declare that the treatment should last for such or such a period. But the length of time for which any remedy is to be used must depend on its effect, and on the nature of the particular case. It is found, however, that the continued use of mineral waters leads to certain disturbances of the system, which have been called crises, such as sleeplessness, colics, and diarrhœa, and to skin eruptions known as *la poussée*. This cause, and also certain peculiarities of the female constitution, have led to the period of three weeks to a month being considered the usual period for treatment. A certain after-treatment is often prescribed —such as persistence in a particular diet, visiting springs or climates of a different and usually of a tonic character, or continuing for a certain time to drink the waters at home. It may be added that the advantage of having recourse to mineral waters is often felt more after than during treatment.

Since improved methods of bottling have been discovered, and the advantage of an additional supply of carbonic acid has been appreciated, the export of waters from their sources has increased enormously, and most of the principal waters can now be advantageously used at home. It may be added that many of the artificial imitations of them are excellent.

The history of the use of mineral waters can only just be alluded to. They have been employed from the earliest periods, and traces of Roman work have been found at most of the European baths which are now in favour,—at almost all the thermal ones. Occasionally new springs are discovered in old countries, but the great majority of them have been long known. They have varied in popularity, and the modes of applying them have also varied, but less so than has been the case with most of the ordinary medicines. Warm waters, and those containing small quantities of mineral constituents, appear to have remained more steadily in favour than any other class within the appropriate sphere of mineral waters, which is limited to the treatment of chronic disease.

The attempt has been made to range mineral waters according to their therapeutic action, according to their internal or external use, but most generally according to their chemical constituents so far as they have been from time to time understood; and a judicious classification undoubtedly is a help towards their rational employment. But their constituents are so varied, and the gradations between different waters are so finely shaded off, that it has been found impossible to propose any one definite scientific classification that is not open to numberless objections. Thus a great many of the sulphur waters are practically earthy or saline ones. Yet because they contain very minute amounts of such a gas as hydrosulphuric acid, an ingredient so palpable as always to attract attention, it is considered necessary to class them under the head of sulphur. The general rule is to attempt to class a water under the head of its predominant element; but if the amount of that be extremely small, this leads to such waters as those of Mont Dore being classified as alkaline or arseniated, because they contain a very little soda and arsenic. The classification in the following table, which is that usually adopted in Germany, has the merit of comparative simplicity, and of freedom from theoretical considerations which in this matter influence the French much more than the German writers. The more important constituents only are given. The amount of solid constituents is the number of parts to one thousand parts of the water; the temperature of thermal springs is added. The waters are classified as indifferent, earthy, salt, sulphuretted, iron, alkaline, alkaline saline—with subvarieties of table waters and purging waters.

TABLE I.—*Typical Mineral Waters.*

	Indifferent. Gastein, 95°–118°.	*Earthy.* Leuk, 123°·8.	*Salt.* Kissingen.	*Salt.* Sea-Water.	*Sulphur.* Aix-la-Chapelle, 113°–140°.	*Iron.* Schwalbach.	*Alkaline.* Vichy, 105°·8.	*Alkaline-Saline.* Carlsbad, 119°–138°.	*Table Water.* Selters.	*Purging Water.* Hunyadi Janos.
Solids.										
Bicarbonate of soda.					·6449	·0206	4·883	1·92	1·2	
,, potash....							·352			
,, magnesia.	·0017	·013	·017	·45	·0506	·2122	·303	·18		
,, calcium...	·0195	·012	1·06	2·38	·157	·2213	·434	·428		
Sulphate of soda..........	·0208	·050			·2831	·0079	·292	2·37		15·9
,, potash	·0135	·038			·1527	·0037		·16		
,, magnesia.....		·308	·588	2·96					·46	16·0
,, calcium.......		1·520	·389	·25						
Sulphide of sodium					·0136					
Chloride of sodium	·0428		5·52	25·21	2·616		·534	1·03	2·2	1·3
,, potash........			·286							
,, *magnesia*.....			·303	3·39						
Carbonate of iron..........	·0005	·023	0·277			·0837		·003	·01	
Silicic acid............. ...	·0496	·036				·0320				
Gases.										
Carbonic acid.............			3·19			5·35	2·6	·76	2·24	·45
Hydrosulphuric acid.....					trace					

In addition to their solid constituents, gas is present in many waters in considerable quantity. There is a little oxygen and a good deal of nitrogen in some of them; the quantity of hydrosulphuric acid, even in strong sulphuric waters, is wonderfully small; but the volume of carbonic acid present is often very large,—for instance, in the case of Kissingen, Schwalbach, and Selters. Carbonic acid is so generally diffused that it is practically a very important agent in the therapeutics of mineral waters. Springs that contain it are far the most agreeable to the taste, and consequently most popular with patients. The immediate effect of the carbonic acid which they contain is that of pleasant stimulation to the stomach and system, although it can scarcely be said to approach, as some have thought, the slighter forms of stimulation from alcoholic drinks. Extremely little appears to be known of its actual operation on the system: a part of what is swallowed is returned by eructation, and a part passes on to the intestines; whether any appreciable quantity reaches the blood is doubtful. There is no question that carbonic acid increases diuresis. Practically it is found to aid digestion, helping the functions of the stomach, and in a slight degree the peristaltic action of the intestines. The increased flow of urine may be caused by its favouring the absorption of water by the stomach. In some baths carbonic acid is so abundant that precautions have to be taken to prevent its tendency to accumulate on account of its heavy specific gravity. Carbonic acid gas, used as a bath, proves stimulating to the skin and to the general system; but its employment has not answered the expectations formed of it.

Indifferent Waters scarcely vary in chemical qualities from ordinary drinking water; but they are usually of higher temperature. Their therapeutic action, which is mainly exercised through baths, has been explained on the theory of peculiarities of their electric or thermal condition, about which we know nothing definite, and on the presence in some of them of a large quantity of nitrogen. It has also been ascribed to the various organic substances in some of them, such as glairin, which when collected is sometimes useful as a cataplasm. These waters are not often much drunk, but any efficiency they may have in dyspepsia and perhaps in neuralgic diarrhœas must be attributed to the favourable action of hot water on the digestion. The waters of this class, especially the hotter ones in the form of baths, are extremely useful in resolving the effects of inflammation, in thickenings of the joints, and in chronic rheumatism and gout. They also are often effective, especially the cooler ones, in neuralgia and in some hysterical affections. They are sometimes prescribed in urinary affections, in which case they probably assist by dilution. The effects of many of these waters are aided by the baths often being situated at considerable elevations and in out-of-the-way spots, whence the Germans called them *Wildbäder*. They are very widely diffused, being found in all quarters of the globe, especially in volcanic districts. There are many in New Zealand; in America the hottest are in the West and in California.

TABLE II.[1]—*Indifferent Waters.*

Locality.	Height in Feet.	Temp. ° Fahr.	For what prescribed.
Evian, Lake of Geneva	1,100	...	Nervous cases, dyspepsia, urinary affections.
Badenweiler, Baden ...	1,425	...	For mild rheumatic treatment; a health resort.
Buxton, England.......	980	82	Gout and rheumatism (nitrogen present).
Schlangenbad, Nassau.	800	80–87	Nervous cases, female disorders, skin.
Sacedon, Spain...........	1,500	85	Rheumatism, gout, cutaneous affections.
Wildbad, Würtemberg.	1,320	90–101	Gout and rheumatism, neuralgia, thickenings.
Pfeffers, Switzerland...	2,115	99	Do. do. do.
Ragatz, do. ...	1,570	95	Do. do. do.
Panticosa, S. Pyrenees.	5,110	85–95	Do. (nitrogen present); special action in phthisis.
Teplitz, Bohemia........	648	101–120	Gout, rheumatism, old injuries, joints or bones.
Gastein, Austria.........	3,315	95–118	Do. do.; soothes nervous system.

Earthy Waters.—These differ chiefly from the indifferent waters in containing an appreciable quantity of salts, among which sulphate or carbonate of lime or of magnesia predominates. The great majority of them are of high temperature. They produce the same effects as the indifferent waters, but are perhaps less efficacious in neuralgic affections, while they are more employed in some of the chronic scaly eruptions. There was formerly a tendency to consider these waters useful in urinary affections; but at the present day it is only the colder ones that have come into repute for the expulsion of gravel and biliary calculi and in the treatment of affections of the bladder generally. Some of them have also of late years been considered to exercise a favourable influence on scrofula, and to be useful in the early stages of pulmonary phthisis. This has been attributed to the salts of lime present in them, although it is known that most of its salts pass through the system unaltered. Many of these baths, such as Leuk and Bormio, enjoy the advantages of great elevation, but Bath, otherwise one of the best of them, lies low.

TABLE III.—*Earthy Waters.*

	Locality.	Height in Feet.	Temp. ° Fahr.	Therapeutic Action.
Cold.	Contrexeville, Vosges........	1,050	....	Special action in calculous affections.
	Lippe Springe, N. Germany	...	...	Supposed to be useful in phthisis.
	Wildungen, do.	...	...	Special use in urinary complaints; contains iron.
	Weissenberg, Switzerland...	2,600	...	Resorted to for pulmonary affections.
	Pougues, France..............	600	...	Dyspepsia, diabetes, hepatic and urinary concretions.
Warm.	Baden, Switzerland...........	1,180	117–122	Rheumatism, gout, paralysis, scaly eruptions.
	Leuk, do.	4,400	93–123	Do., some female complaints.
	Bormio, North Italy..........	4,400	86–104	Do. do. ; old sprains.
	Lucca, Italy	...	108–122	Do. do. do.
	Bath, England..................	...	108–122	Do. do. do.
	Dax, south of France.........	1,400	139	Do. do.
	B. de Bigorres, Pyrenees.....	1,800	64–123	Do.; chlorosis, neuralgia.

[1] In this and the following tables a selection is given of some of the best-known mineral waters in various European countries that possess establishments. Their chief peculiarities of elevation, of temperature, and constituents are briefly noted. The curative effects, necessarily alluded to very generally, are those usually attributed to them.

Salt Waters are so called from containing a predominant amount of chloride of sodium. They also generally contain chlorides of magnesia and of lime, and occasionally small amounts of lithium, bromine, and iodine. They further often contain a little iron, which is an important addition. The great majority of the drinking wells have a large supply of carbonic acid. There are cold and hot salt springs. Sometimes they are used for drinking, sometimes for bathing; and the double use of them is often resorted to.

The normal quantity of common salt consumed daily by man is usually set down at about 300 grains. The maximum quantity likely to be taken at any well may be 225 grains, but commonly not more than half of that amount is taken. The increase to the usual daily amount is therefore probably not much more than one-third. Still it may be presumed that the action of a solution of salt on an empty stomach is different from that of the same amount of salt taken with food. Salt introduced into the stomach excites the secretion of gastric juice, and favours the peristaltic actions, and when taken in considerable quantity is distinctly aperient. We thus see how it is useful in dyspepsia, in atony of the stomach and intestines, and sometimes in chronic intestinal catarrh. Salt when absorbed by the stomach appears again in the urine, of which it increases the amount both of fluid and of solid constituents, especially of the urea. It seems therefore to be pretty certain that considerable quantities of salt taken into the circulation increase the excretion of nitrogenous products through the urine, and on the whole accelerate the transformation of tissue. Salt is thus useful in scrofula by stimulating the system, and also in anæmia, especially when iron is also present. In some German stations, as at Soden, carbonated salt waters are considered to be useful in chronic laryngitis or granular pharyngitis.

Baths of salt water, as usually given, rarely contain more than 3 per cent. of chloride of sodium, some of the strongest perhaps from 8 to 10 per cent. Their primary action is as a stimulant to the skin, in which action it is probable that the other chlorides, especially that of calcium, and still more the carbonic acid often present, co-operate. In this way, and when aided by various processes of what may be termed water poultices and packing, they are often useful in removing exudations, in chronic metritis and in some tumours of the uterus, and generally in scrofula and rachitis, and occasionally in some chronic skin affections.

The French accord high praise to some of their thermal salt waters in paralysis, and some German ones are used in a similar way in spinal affections. The salt waters are sometimes so strong that they must be diluted for bathing. In other cases concentrated solutions of salt are added to make them sufficiently strong. These waters are widely diffused, but on the whole Germany is richest in them, especially in such as are highly charged with salt. The Kissingen springs may be considered as typical of the drinking wells, and sea-water of bathing waters. The air of salt-works and pulverization of the water are employed in German baths as remedial agents.

Salt springs are found in many quarters of the world, but the chief carbonated groups for drinking purposes occur in Germany, and at Saratoga in America, where very remarkable wells indeed are to be found. France and England have no springs of this class. The stronger wells, used chiefly for bathing, occur where

TABLE IV.—*Salt Springs.*

	Locality.	Temp. ° Fahr.	Therapeutic Action.
Cold.	Soden, near Frankfort	...	Dyspepsia, anæmia, scrofula, special for throat and phthisis.
	Homburg, do.	...	Dyspepsia, slighter hepatic affections, chlorosis, gout.
	Kissingen, Bavaria	...	In all essentials the same.
	Pyrmont, North Germany	...	Better known for its iron; has a good salt drinking spring.
	Kreuznach, near Bingen	...	A salt well without carbonic acid used in scrofula and anæmia; bathing more important.
Warm.	Wiesbaden, Nassau	155	Used in dyspepsia and gout; the bathing is most important.
	Baden-Baden	156	Still milder water; uses similar; gout.
	Bourbonne, Haute-Marne	114–149	Rheumatism, neuralgia, effects of malaria.
	Balaruc, South France	116·6	Do.; special for treatment of paralysis.
	Salins, Moutiers, Savoy (1450 ft.)	96	Scrofula, anæmia, loss of power, sexual disorders.
	Brides, Savoy (1700 ft.)	95	Act on liver and digestive canal; used for obesity.
	Acqui, North Italy	169	Rheumatism; special treatment with the bath deposit.
	Abano, do.	185	Chiefly as baths; mud of bath used for poultice.
	Caldas de Mombuy, near Barcelona	153–158	Rheumatism, sciatica, old injuries.
	Cestona, Guipuzcoa, Spain	88–94	Rheumatism, indigestion, bronchitis.

Almost all the above stations have several springs of various strengths: the cold may be said to vary from 14 to 5·8 per cent. of chloride of sodium; the warm are generally weaker, perhaps varying from 6·8 to 1·6.

there are salt-bearing strata, as in Germany, Galicia, Italy, Switzerland, France, and England. Very powerful waters of this class are those of St Catherines in Canada.

The presence of minute portions of *iodine* or *bromine* in salt waters is by no means infrequent, and they appear in considerable quantity in some few. It is, however, extremely doubtful whether any known spring contains a sufficient quantity of iodine, still more of bromine, to act specially on the system, even if that action were not necessarily superseded by the presence of the large quantity of other salts with which they are associated. Some of the best known springs of the kind are:—Challes, Wildegg, Castrocaro, Hall, Adelheid's Quelle, Krankenheil, Kreuznach, Woodhall Spa.

Iron or Chalybeate Waters.—Iron usually exists in waters in the state of protoxide or its carbonate, less frequently as sulphate or crenate, and very rarely if at all as chloride. The quantity present is usually extremely small. It may be said to vary from ·12 to ·03 in the 1000 parts of water. Some wells considered distinct chalybeates contain less than ·03. Many wells, especially in Germany, have a rich supply of carbonic acid, which is unfortunately wanting in French and English ones.

It has long been the prevalent idea that want of iron in the blood is the main cause of chlorosis and of other anæmic conditions, and that these conditions are best relieved by a supply of that metal. Since the detection of it in hæmoglobuline this view has been still more popular. It is pretty certain that the blood contains 37 to 47 grains and the whole system 70 to 74 grains of iron; and it has been calculated that in normal conditions of the system somewhat more than one grain of iron is taken daily in articles of food, and that the same amount is passed in the fæces; for although the stomach takes the iron up it is excreted by the alimentary canal mainly, it being doubtful whether any is excreted in the urine. It is possible by drinking several glasses to take in more than a grain of carbonate of iron in the day, equivalent to half that amount of metallic iron. It has further been ingeniously reckoned from practice that 10 to 15 grains of metallic iron suffice to supply the deficiency in the system in a case of chlorosis. It is thought probable that a portion of the iron taken up in water is in certain pathological states not excreted, but retained in the system, and goes towards making up the want of that metal. But, whether this or any other explanation be satisfactory, there is no question as to the excellent effects often produced by drinking chalybeate waters (especially when they are carbonated), and by bathing in those which are rich in carbonic acid after they have been artificially heated. As regards the drinking cure we must not, however, forget that carbonate and chloride of sodium, and also the sulphate, are often present and must be ascribed a share in the cure. Thus chloride of sodium is a power-

TABLE V.—*Stronger Salt Waters.*

Locality.	Chloride of Sodium in 1000 parts of Water.	Therapeutic Application.
Rheinfeld, Aargau, Switzerland	311	Scrofula, effects of inflammation, chronic exudations, some chronic exanthemas, rheumatism, uterine infiltrations.
Salzungen, North Germany	256	Do. do.
Ischl, Austria (1440 ft.)	236	Do. do.
Hall, Tyrol (1700 ft.)	235	Do. do.
Reichenhall, near Salzburg (1800 ft.)	224	Do. do.
Bex, Rhone Valley (1400 ft.)	156	Do. do.
Castrocaro, Tuscany	53	Do. do
Droitwich, near Worcester	233·6	Do. do.
Sea Water	30·4	
Rehme, Westphalia (92° F.)	24–85	Do.; special use in locomotor ataxia.
Nauheim, Wetterau (80°–105° F.)	29	Do. do.

TABLE VI.—*Iron Waters.*

Locality	Height in Feet.	Carb. of Iron.	Therapeutic Use.
Rippoldsau, Black Forest	1,886	·12	For anæmic conditions; laxative.
Homburg, near Frankfort	...	·10	Do. do. do.
Elster, Saxony	1,465	·08	Do. do. do.
Liebenstein, North Germany	911	·08	
Schwalbach, Nassau	900	·05	Do.; much of a ladies' bath.
Bocklet, near Kissingen	660	·08	Do.
Griesbach, Black Forest	1,614	·07	Do.; laxative; a ladies' bath.
Franzensbad, Bohemia	1,293	·07	Do. do. do.
Pyrmont, Germany	...	·07	Do.
Spa, Belgium	1,000	·06	Do.
Petersthal, Black Forest	1,333	·04	Do.; laxative.
St Moritz, Engadine, Switzerland	5,464	·03	Do.; sought for its air.
Forges-les-Eaux, France	...	·06	Do.
La Malou, Hérault, France (temp. 88°)	...	·03	Do.
Recoaro, North Italy	1,463	·04	Do.
Tunbridge Wells, England	...	·06	Do.; deficient in carbonic acid.
Muspratt Spring, Harrogate (chloride)	...	·15	

ful adjuvant in the strong Stahl Quelle of Homburg and in the Putnam Well at Saratoga. A whole category of female complaints is treated successfully with these waters. Indeed anæmia from any source, as after fever or through loss of blood, and enlargements of the spleen, are benefited by them. The stimulating action of the copious supply of carbonic acid in steel baths is a very important adjuvant; no one now believes in direct absorption of iron from the bath. Iron waters are scarcely ever thermal. They are extremely common in all countries,—frequently along with sulphuretted hydrogen in bogs, and near coal-measures. But such springs and non-carbonated wells generally are weak, and not now held in much esteem.

It may be added that some of the strongest known iron wells are *sulphated* or *aluminated*. They are styptic and astringent, and can only be used diluted. They are sometimes useful as an application to ulcers and sores. Such springs have often been brought into notice, but never retain their popularity. They are known in the Isle of Wight, in Wales, in Scotland, as well as in Elba, &c.; and of late years the Bedford Alum and Oak Orchard Springs, U.S., have been brought into notice, the latter containing 10 grains of free sulphuric acid in the pint. All such springs have been considered useful in scrofula, anæmia, and chronic diarrhœas.

Sulphur Springs.—Waters having the odour of hydrosulphuric acid, however slightly, are usually called sulphur ones. They owe their smell sometimes to the presence of the free acid, sometimes to sulphides of sodium, calcium, or magnesia, and sometimes to both. Hydrosulphuric acid is absorbed more freely by cold than by hot water, and is therefore most abundant in cold springs. The sulphides decompose and give off the gas. Most of these springs occur near coal or shale measures, or strata containing fossils, or in moors and in places generally where organic matter is present in the soil or strata. Many of them contain so little mineral impregnation that they might as well be classed among the indifferent or earthy waters. One group contains a considerable amount of chloride of sodium, another of sulphate of lime, while a third has little mineral impregnation, but contains sulphides.

Hydrosulphuric acid is a strong poison, and its action on the system has been pretty well ascertained. It has been assumed that the gas in mineral waters acts similarly, though in a modified degree; but there is next to nothing absolutely known of the action of the small quantities of the gas that are present in mineral waters, and which certainly have no toxic effect. It has been assumed that this gas has some special action on the portal system and so on the liver. On the connexion of metallic poisoning with the liver has been founded the idea that sulphur waters are useful in metallic intoxication. Drinking large quantities of these waters, especially of such as contain sulphates or chlorides of sodium or magnesia, combined with hot baths and exercise, may help to break up albuminates, but there is no proof of the action of the sulphur.

For similar reasons, and primarily to counteract mercurial poison, sulphur waters have been considered useful in syphilis. But it may be well to remember that at most baths mercury is used along with them. No doubt they are frequently, like other warm waters, useful in bringing out old eruptions, acting in this way as a test for syphilitic poison, and in indicating the treatment that may be required. Sulphur waters, both hot and cold, are used in gout and rheumatism, in dyspepsia, in hepatic and cutaneous affections; and of late years inhalation of them has been popular in phthisis and in laryngeal affections. They have long been popular remedies in cutaneous affections. While so much doubt has been cast on the action of the sulphur of these waters, it may be admitted that the sulphides are probably decomposed in the stomach and hydrosulphuric acid generated. That gas is probably a slight stimulant to the intestine. What hydrosulphuric acid reaches the blood is eliminated by the lungs. There seems to be no doubt that the gas is absorbed in small quantities by the skin.

TABLE VII.—*Cold Sulphur Springs.*

Locality.	Hydrosulphuric Acid absorbed in Water.	Sulphide of Sodium.
Eilsen, Schaumburg-Lippe	42·3	...
Meinberg, Lippe-Detmold	23·1	·008
Gurnigel, Switzerland (3600 ft.)	15·1	...
Leuk, do. (3593 ft.)	44·5	...
Challes, Savoy (900 ft.)	...	·478
Enghien, near Paris	...	·106
Uriage, Isère, France (1500 ft.)	7·34	...
Harrogate, England	...	·207
Strathpeffer, Scotland	...	·026
Lisdunvarna, Clare, Ireland	...	...

TABLE VIII.—*Warm Sulphur Springs.*

Locality.	Height in Feet.	Temp. ° Fahr.	Sulphide of Sodium.	Hydrosulphuric Acid absorbed in Water.
Aix-la-Chapelle, Germany	534	131–140	·01	·3
Baden, near Vienna	...	95–115	·052	2·5
Schinznach, Switzerland	1,060	80–92	...	37·8
Lavey, Rhone Valley	1,350	92–113	...	3·5
Hercules Bad, Banat	500	110	...	42·6
Aix-les-Bains, Savoy	765	108·5	...	27·2
Luchon, Pyrenees	2,000	135·5	·07	...
Baréges, do.	4,100	113	·04	...
Amélie-les-Bains, Pyrenees	810	87–147	·01	...
Cauterets, do.	3,254	71–134	·02	...
Eaux Bonnes, do.	2,400	90·5	·02	...
Archena, Murcia, Spain	...	126	...	...

It is in sulphur waters chiefly that glairin and baregin occur. This peculiar organic substance has been found both in American and in European springs. Cold sulphur springs are very widely diffused throughout the world. Thermal ones are not so common. Perhaps the largest though not the strongest group of the latter is to be found in the Pyrenees. We may remark again how very little hydrosulphuric acid there is in many of the most favourite sulphur springs, including the very popular White Sulphur ones of Virginia. There seems to be something peculiarly unsatisfactory in the analysis of sulphur waters, and there has been difficulty in constructing the following imperfect tables.

Some of the most powerful cold wells are those of Challes (with its very peculiar water), Leuk, and Harrogate. Uriage has a very large amount of chloride of sodium in its springs. Cold sulphur waters are on the whole more used in liver and indigestion than warm ones. The general effects of warm sulphur waters differ so little at the various baths as to make it difficult to mention anything special to particular localities. Schinznach has a reputation in skin complaints, Cauterets, Eaux Bonnes, and Challes in laryngeal affections, the two Aixes, Luchon, and Archena in syphilis.

Alkaline Waters are such as contain carbonate (chiefly bicarbonate) of soda, along with an excess of carbonic acid. Of the action of those carbonates it is known that when taken into the stomach they are neutralized by the gastric juice, and converted into chloride of sodium. On their introduction into the stomach they produce an increased flow of gastric juice. If given during or immediately after meals in any quantity, they impede digestion. They slightly increase peristaltic action, but only feebly, unless assisted by other salts. They act slightly as diuretics. Of the connexion between the biliary system and alkalies, which undoubtedly exists, not much is known with certainty. The alkalization of the blood by them is assumed by many, but not proved. It is very doubtful whether they reduce the quantity of fibrine in the blood, and thus induce a

TABLE IX.—*Alkaline Waters.*

CLASS I.—*Simple Alkaline.*

Locality.	Carb. Soda.	Therapeutic Uses.
Vals, South France	7·1	Catarrh of stomach, gout, renal and biliary calculi, liver complaints, diabetes.
Bilin, Bohemia	4·2	Do. do. do.
Vichy, France (105° F.)	5·1	Do. do. do.
Neuenahr, Rhineland (92°–97° F.)	1·0	Mucous catarrh; diabetes specially.
La Malou, France (97° F.)	...	Do.; sedative effect on nervous system.
Vidago, Portugal	...	Do., gout, urinary affections—"The Portuguese Vichy."

CLASS II.—*With Chloride of Sodium varying from 4·3 to 1 in amount.*

Locality.	Height in Feet.	Temp. ° Fahr.	Carb. Soda.	Therapeutic Uses.
Luhatschowitz, Moravia	1,600	...	8·4	Springs rich both in carb. soda and chl. sodium.
Tönnistein, Rhine Valley	...	...	2·5	Light antacid tonic to stomach
Ems, Nassau	...	85–115	2·0	*Special in female complaints and mucous membrane.*
Ischia, Italy	...	up to 170	2·0	Specially rheumatism and female complaints.
Royat, Auvergne	1,400	80–95	1·3	*Do.* and some skin affections.
Mont Dore, do.	3,300	100–114	...	Asthma, chronic laryngitis.
Bourboule, do.	2,800	107–125	...	Scrofula, rachitis, cutaneous affections.

CLASS III.—*With Sulphate of Soda varying from 5·2 to 2 in amount, and Carbonate of Soda varying from 3·55 to ·51 in amount.*

Locality.	Height in Feet.	Therapeutic Uses.
Elster, Saxony	1,460	Action on abdominal organs, female complaints.
Marienbad, Bohemia	1,012	Do.; special use in obesity.
Franzensbad, do.	1,293	Do.; specially a ladies' bath.
Tarasp, Lower Engadine	4,000	Powerful action on abdominal viscera.
Carlsbad, Bohemia (121°–164° F.)	1,200	Gout, liver affections, biliary and renal calculi, diabetes.

lowered state of the system, or whether they have any direct tendency to combine with fat and carry off a portion of superfluous adipose tissue. Their excess of carbonic acid, through its action on the stomach, favours the operation of alkaline waters. They have been classed as follows:—(I.) simple alkalines, where carbonate of soda is the main agent; (II.) waters containing in addition some chloride of sodium; (III.) waters containing sulphates of soda or of magnesia. All these classes may be said to be used in gout, lithiasis, affections of the liver, catarrh, and obstructions of the gall ducts, in dyspepsia, chronic catarrh of the stomach, and diarrhœa, in obesity, and in diabetes. Some of the waters of the second class are supposed to influence bronchial catarrhs and incipient phthisis, while the more powerful sulphated waters of the third class are especially useful in catarrh of the stomach, and in affections of the biliary organs; of these only one of importance (Carlsbad) is thermal. The rival cold waters of Tarasp contain twice as much carbonate of soda. The cold ones are chiefly used internally, the thermal ones both internally and externally. The latter, besides acting as warm water, slightly stimulate the skin when the carbonic acid is abundant, and the carbonate of soda has some slight detergent effect on the cutaneous surface like soap. These waters are unknown in England. They are most abundant in countries of extinct volcanoes.

Classes I. and II. of alkaline waters may be said to have a subvariety in *acidulated* springs or carbonated waters, in which the quantity of salts is very small, that of carbonic acid large. These table waters are readily drunk at meals. They have of late years been so widely exported as to be within the reach almost of every one. Their practical importance in aiding digestion is in reality much greater than one could expect from their scanty mineralization. They are drunk by the country people, and also largely exported and imitated. They are very abundant on the Continent, and, although some of the best-known ones enumerated below are German and French, they are common in Italy and elsewhere:—Heppingen, Roisdorf, Landskro, Apollinaris, Selters, Brückenau, Gieshübel, all German; St Galmier, Pougues, Chateldon, French.

Associated with Class III. is that of the strongly *sulphated* waters known in Germany as bitter or purging waters, which have of late deservedly come into use as purgative agents. They are almost wanting in France and in America, and there are no very good ones in England. The chief supply is from Bohemia and Hungary. The numerous waters of Ofen are the best-known, and some of them are stronger than the Hunyadi, of which an analysis has been given in Table I. They are easily imitated. Some of the best-known are Ofen, Püllna, Saidschütz, Friedrichshall, Birmerstorff, Kissingen.

Two other classes of waters demand a few words of notice. The French have much faith in the presence of minute quantities of arsenic in some of their springs, and trace arsenical effects in those who drink them, and some French authors have established a class of *arsenical* waters. Bourboule in Auvergne is the strongest of them, and is said to contain $\frac{1}{12}$th of a grain of arseniate of soda in 7 ounces of water. Baden-Baden, according to Bunsen's latest analysis, has a right to be considered an arsenical water. It is, however, extremely doubtful whether the small amounts of arseniate of soda which have been detected, accompanied as they are by preponderating amounts of other salts, have any actual operation on the system. The following are among the most noted springs:—Bourboule, Mont Dore, Royat, Salies (Bigorres), Plombières, Baden-Baden.

Of late years *lithium* has been discovered in the waters of Baden-Baden; and various other places boast of the amount of that substance in their springs. Indeed a new bath has been established at Assmannshausen on the Rhine in consequence of the discovery of a weak alkaline spring containing some lithium. Not very much is known of the action of lithium in ordinary medicine, and it undoubtedly does not exist in medicinal doses even in the strongest springs. Among these springs are those of Baden-Baden, Assmannshausen, Elster, Royat, Ballston Spa, and Saratoga (U.S.).

American Mineral Waters.—The number of springs in the United States and Canada to which public attention has been called on account of their supposed therapeutic virtues is very large, amounting in all to more than three hundred. Of this number comparatively few are in Canada, and of these not more than six (St Catharines, Caledonia, Plantagenet, Caxton, Charlottesville, and Sandwich) have attained general celebrity. The first three belong to the saline class, the Caxton is alkaline-saline, and the last two are sulphur waters. The St Catherines is remarkable for the very large amounts of sodium, calcium, and magnesium chlorides which it contains, its total salts (450 grains in the pint) being more than three times the quantity contained in the brine-baths of Kreuznach in Prussia. The Charlottesville and Sandwich springs likewise surpass the noted sulphur-waters of Europe in their excessive percentages of sulphuretted hydrogen, the former containing more than 3 and the latter 4·72 cubic inches of this gas in the pint.

The mineral springs in the United States are very unequally distributed, by far the larger number of those which are in high medical repute occurring along the Appalachian chain of mountains, and more especially on or near this chain where it passes through the States of Virginia, West Virginia, and New York. The Devonian and Silurian formations which overlie the Eozoic rocks along the course of the Appalachian chain have been greatly fissured—the faulting of the strata being in some places of enormous magnitude—by the series of upheavals which gave rise to the many parallel mountain ridges of the Appalachians. In many places the springs occur directly along the lines of fault. The various classes of mineral waters are likewise very unequally represented, the alkaline springs, and those containing Glauber and Epsom salts, being much inferior to their European representatives. On the other hand, the very numerous and abundant springs of Saratoga compare very favourably with the Selters and similar saline waters, and among the many American chalybeate springs the subclass represented by the Rockbridge Alum is unequalled in regard to the very large percentages of alumina and sulphuric acid which it contains. Besides its greater amount of mineral constituents (135 grains per pint), the Ballston spring surpasses the similar saline waters of Homburg, Kissingen, Wiesbaden, and Selters in its percentage of carbonic acid (53 cubic inches). It is also remarkable for the very large proportion of carbonate of lithia, amounting to 0·701 grains. Thermal springs are specially numerous in the territories west of the Mississippi and in California. Those in the east mostly occur in Virginia along the southern portion of the Appalachian chain; in the middle and New England States Lebanon is the only important thermal spring. Subjoined is a list of thirty American springs, the design being to represent as many of the more noted spas as possible, while at the same time enumerating the best representatives of the classes and subclasses into which mineral waters are divided according to the German method of classification.

	Designation and Locality.	Therapeutic Application
Indifferent (Thermal).	Lebanon, Columbia Co., N.Y. (73° F.)	
	Healing, Bath Co., Va. (88° F.)	Scrofulous ulcers and ophthalmia, ozæna, chronic diarrhœa and dysentery, secondary and tertiary syphilis.
	Warm, Bath Co., Va. (98° F.)	Chronic and subacute rheumatism, gout, neuralgia, nephritic and calculous diseases.
	Hot, Bath Co., Va. (110° F.)	Chronic rheumatism, gout, diseases of liver, neuralgia, contractions of joints.
	Paso Robles, San Luis, Obispo Co., Cal. (122° F.)	
	Hot, Garland Co., Ark. (93°–150° F.)	Dartrous diseases of skin, functional diseases of uterus, chronic mercurial and lead poisoning.
Calcareous and Earthy.	Gettysburg, Adams Co., Penn.	Calculus, gravel, catarrh of stomach or bladder, dyspepsia.
	Sweet, Monroe Co., W. Va. (74° F.)	Gravel, dyspepsia (diuretic, diaphoretic).
	Berkeley, Morgan Co., W. Va. (74° F.)	Neuralgia (restorative).
	Alleghany, Montgomery Co., Va.	Purgative, diuretic.
	Bethesda, Waukesha Co., Wis.	Diabetes mellitus, gravel, inflammation of bladder, dropsy, albuminuria (diuretic).
Sulphur.	Lower Blue Lick, Nicholas Co., Ky.	Aperient and alterative.
	Sharon, Schoharie Co., N. Y.	Do. do.
	White Sulphur, Greenbrier Co., Va.	Dartrous skin diseases, diseases of the bladder, jaundice, dyspepsia.
	Salt Sulphur, Monroe Co., W. Va.	Do.; scrofula and syphilis.
Epsom Salt.	Bedford, Bedford Co., Penn.	Anæmia, gravel, calculus (strongly diuretic).
Common Salt.	St Catherines, Ontario, Canada	Rheumatism, gout, scrofula, neuralgia.
	Caledonia, Ontario, Canada	Rheumatism, gout.
	Hathorne, Saratoga, N.Y.	Dyspepsia, jaundice, abdominal plethora.
	Ballston, Saratoga Co., N.Y.	Do. do. do.
Iron.	Oak-Orchard Acid, Genesee Co., N.Y.	Ulcers, diseases of the skin, passive hæmorrhages, atonic diarrhœa (has 10 grains of free sulphuric acid in the pint).
	Rawley, Rockingham Co., Va.	Chlorosis and anæmia generally; tonic.
	Sweet Chalybeate, Alleghany Co., Va.	Do. do. do.
	Rockbridge Alum, Rockbridge Co., Va.	Scrofula, chronic diarrhœa.
	Cooper's Well, Hinds Co., Miss.	Anæmia, chlorosis, chronic diarrhœa, dropsy.
Glauber Salt.	Crab Orchard, Lincoln Co., Ky.	
	Midland, Midland Co., Mich.	
Alkaline.	Bladon, Choctaw Co., Ala. (carbonated alkaline).	
	Congress, Santa Clara Co., Cal. (saline alkaline)	
	St Louis, Gratiot Co., Mich. (simple alkaline)	Dyspepsia, neuralgia, chronic and subacute rheumatism.

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MINERVA (*i.e.*, *menes-va*, endowed with mind) was the Roman goddess who presided over all handicrafts, inventions, arts, and sciences. She was probably an Etruscan deity, but her character was modified on Roman soil through her identification with the Greek Pallas Athena (see ATHENA). No legend of her birth is recorded; the Roman deities were abstractions, not distinct persons with an individual history. Her chief worship in Rome was in the temple built by Tarquin on the Capitol, where she was worshipped side by side with Jupiter and Juno. This foundation may be assigned to Etruscan influence. She had also an old temple on the Aventine, which was a regular meeting-place for dramatic poets and actors. The dedication day of the temple and birthday of the goddess was March 19, and this day was the great festival of Minerva, called *quinquatrus* because it fell on the fifth day after the Ides. The number five was sacred to the goddess. All the schools had holidays at this time, and the pupils on reassembling brought a fee (*minerval*) to the teachers. In every house also the *quinquatrus* was a holiday, for Minerva was patron of the women's weaving and spinning and the workmen's craft. At a later time the festival was extended over five days, and games were celebrated. This feature is evidently due to the Græcizing conception of Minerva as the goddess of war. To this same Græcizing tendency we must attribute the *lectisternium* to Minerva and Neptune conjointly after the battle of the Trasimene Lake. The 23d had always been the day of the *tubilustrium*, or purification of the trumpets, so that the ceremony came to be on the last day of Minerva's festival. Trumpets were used in many religious ceremonies; and it is very doubtful whether the *tubilustrium* was really connected with Minerva. There was another temple of Minerva on the Cælian Hill, and a festival called the lesser *quinquatrus* was celebrated there on June 13–15, chiefly by the flute-players.

Minerva of the Cælian temple was called Capta; June 19 was the foundation day of this temple and the birthday of the goddess. The *palladium*, an archaic image of Pallas, was brought from Troy to Lavinium, and thence to Rome by the family of the Nautii; it was preserved in the temple of Vesta as a pledge of the safety of the city. There are some traces of an identification of Minerva with the Italian goddess Nerio, wife of Mars; it is probable that March 19 was originally a feast of Mars.

Besides Preller, *Röm. Myth.*, and Hartung, *Relig. d. Römer*, &c., see Jordan, *Ephem. Epigraph.*, i. 238; Mommsen, *C. I. L.*, i. 388; Usener, *Rhein. Mus.*, xxx. 222.

MINGRELIA, a former principality of Transcaucasia, which became subject to Russia in 1804, and since 1867 has constituted three circles of the government of Kutais—Letchgum, Senakh, and Zugdidi. The country corresponds to the ancient Colchis; and Izgaur or Iskuriah on the Black Sea coast, which was the capital during the period of Mingrelian independence under the Dadian dynasty, is to be identified with the ancient Dioscurias, a colony of Miletus. The Mingrelians (still almost exclusively confined to the Mingrelian territory, and numbering 197,000) are closely akin to the Georgians. See CAUCASUS, vol. v. p. 257, and GEORGIA.

MINIATURE is a term which by common usage has come to be applied to two different branches of painting. Derived from the Latin word *minium*, the red pigment used in the primitive decoration of MSS., in the first place it is the technical word employed to describe a painting in a MS.; and, from the fact of such pictures being executed on a reduced scale, it has its secondary and modern signification of a small, or miniature, portrait. In the latter sense it belongs to the general subject of painting. Here it is proposed to trace the development of the miniature in MSS. of the different schools of Europe.

The rise of the art of ILLUMINATION, in which the miniature plays so important a part, has been described under that heading; and something has been said in that place about the earliest extant specimens of miniature painting. Unfortunately we cannot with any certainty reach farther back than the 4th century for the most ancient of them; and all remaining examples between that period and the 7th century in Greek and Latin MSS. can be counted on the fingers. The two famous codices of Virgil in the Vatican Library stand pre-eminent as the most ancient Latin MSS. decorated with paintings. The miniatures in the first of them, the *Codex Romanus*, are large and roughly yet boldly executed paintings, which have no pretension to beauty, and are simply illustrations; but they are as old as the 4th century, and are of the highest value in enabling us to appreciate the debased style to which classical art had descended, and which no doubt was more largely employed than we might think. The second MS., the *Schedæ Vaticanæ*, which may also be assigned to the 4th century, is far more artistic and retains a good deal of the grace of classic art. Of the same kind, but of rather later date, are the fragments of the *Iliad* in the Ambrosian Library at Milan, the miniatures of which are generally of excellent design. Next comes the Dioscorides of the Imperial Library at Vienna, with its semiclassical portrait-miniatures executed at the beginning of the 6th century. Of a rather later period are the paintings which illustrate the Greek MS. of Genesis in the same library. A far finer and older MS. of the same book of the Pentateuch once existed in the Cottonian Library, but was almost totally destroyed by fire. The few fragments of the miniatures which once filled this volume, and which were of the 5th century, are sufficient to show what excellent work could be done in the capital of the eastern empire, from whence the MSS. most probably came. The late interesting discovery of an illustrated MS. of the Gospels in Greek, of the latter part of the 6th century, at Rossano in southern Italy, adds another number to our scanty list of early volumes of this class, which is closed by the Latin Pentateuch in the library of the earl of Ashburnham. This last MS., however, is not older than the 7th century. It was executed in Italy, and is adorned with many large miniatures, not of high artistic merit, but of great interest for the history of painting and of costume.

Coeval with the MSS. which have just been enumerated are the beautiful mosaics and wall-paintings which are seen at Rome, Ravenna, and in other parts of Italy, serving as standards of comparison and carrying on the history of art where MSS. fail us. The strong and ever-increasing Byzantine element which appears in these works prepares us to find the predominance of the same influence when we again pick up the broken thread of the history of miniature painting. We may then, at this point, turn for a moment to the east of Europe and state briefly what remains of Greek art in MSS. Of Greek miniatures there are still many fine examples extant, but, excepting those which have been noticed above, there are few which are earlier than the 11th century. At this period the miniature appears in the set form which it retained for the next two or three hundred years; and the connexion between its

style and that of the mosaics is too evident for us to be at a loss to explain the course of development. The figure drawing is delicate, but rather exaggerated in length; the colours are brilliant; and the whole effect is heightened by glittering backgrounds of gold. In some few instances, however, the Greek artist breaks away from conventionalism, and, especially when pourtraying the divine features of the Saviour or some subject which deeply stirs his feelings, he surprises us with the noble dignity with which he invests his figures. Minuteness also caught the fancy of these Byzantine miniaturists; and there still remain MSS., such as Psalters and saints' lives, adorned throughout with delicate little drawings of great symmetry and beauty. The ornamentation which was employed in Greek MSS. in the period of which we are speaking, either as frames for miniatures or as borders or head-pieces, is designed evidently after Eastern types, and has more than an accidental likeness to the patterns which are seen in the tapestries and prayer-carpets of Persia. After the 13th century decadence sets in, and we need not follow the course of Byzantine art in MSS. farther than to notice that immediately from it sprang such national styles as those of Russia, Bulgaria, and modern Greece.

Meanwhile, in the West, under the fostering care of Charlemagne, arose a great school of decoration in MSS., which at the close of the 8th and beginning of the 9th century were multiplied and enriched with all the splendour that colours and gilding could give to them. But the books thus ornamented were almost always copies of the Gospels, or Bibles, or church service books, which afforded little scope for invention. Hence among the miniatures of this period we have an endless repetition of portraits of the evangelists, drawn, for the most part, in a lifeless way after Byzantine traditions, and degenerating, as time passes, into positive ugliness. The few miniatures of other descriptions, such as Biblical illustrations, show no great merit, and a half-barbaric splendour was generally preferred to artistic effect. But an exception must be made in regard to the style of drawing found in the MS. known, on account of its present resting-place, as the Utrecht Psalter. This volume is filled from beginning to end with delicately drawn pen illustrations, designed and executed with a facility which, compared with the mechanical and clumsy drawing of other Continental MSS. of the period, is astonishing. And these drawings are of particular interest for us, as they are of the style which was adopted in England and which gives to Anglo-Saxon art its distinctive aspect. Executed about the year 800 or early in the 9th century, and probably in the north of France, the volume was soon brought to England, where, however, MSS. of the same kind, it may be assumed, had long before been introduced. The light "fluttering" outlines of the drapery and other details of the drawings seem to suggest that the original models were derived directly from Roman life, and perhaps partly copied from sculpture; but those models must have gone through many modifications before passing into the style of the drawings of the Psalter. That the MS. was copied from an older one there can be scarcely a doubt; and it is not impossible that the original archetype may date back some centuries earlier. May not MSS. which St Augustine and his successors brought from Rome have contained drawings of the same kind? This style of drawing was, at all events, adopted and became nationalized in England; but it had there a rival in the Irish school of ornamentation, introduced from the north of the island. The early civilization of Ireland placed her in the van of art development in these islands. The wonderfully intricate interlaced designs which render Irish MSS. of the 7th and 8th centuries such marvels of exact workmanship derive their origin, in all probability, from the metal-work of earlier ages. But, apart from ornamentation, the Irish miniatures of saints and evangelists are extraordinary and grotesque instances of purely mechanical drawing, which cause us to wonder how the same eyes and hands which assisted in the creation of such beautiful specimens of pure ornament could tolerate such caricatures of the human shape. The explanation is perhaps to be found in superstitious regard for tradition. This style of art was carried by the monks to Iona and thence to Lindisfarne, where was founded the school which produced, in the 8th and 9th centuries, the richly ornamented codices of Durham. While, then, Byzantine models were copied on the Continent, the free drawing introduced from the south and the intricate ornamentation brought in from the north were practised in England; but the free drawing, with its accompanying decoration copied from foliage, and gradually developing into beautiful borders harmoniously coloured, gained the day, and lasted down to the time of the Norman Conquest. The one great fault of this latter style of drawing strikes the eye at the first glance. This is the inordinate length of limb with which the human figures are endowed. But this blemish is forgotten when one comes to appreciate the many points of merit in the designs.

In Italy, after a long period of inactivity, two very different styles of decoration of MSS. sprang into existence. The first of these was that of the Lombardic school, which is distinguished by intricate patterns and bright colouring. The large initial letters which are found in the MSS. of the 11th and 12th centuries, the best period of this style, are often a perfect maze of interlaced bands and animal forms, and are extremely handsome and effective. Figure drawing, however, seems to have been but little practised by the Lombardic artists, but such as there is appears on a broad scale and well executed. In the collections of Monte Cassino are some of the best examples of this school. In the second style which developed in Italy the Byzantine influence is at first most marked. Indeed, among its early specimens of the 13th century are some which might pass for the work of Greek artists. But the genius of the Italians soon assimilated the foreign element, and produced a national school which spread throughout the peninsula and afterwards extended its influence to southern France and Spain. It is, however, remarkable that in a country which produced such fine pictures and wall-paintings at an early date there is comparatively little miniature painting in contemporary MSS. A curious and early instance of this kind of art occurs in a MS. in the British Museum, written and ornamented with a series of miniatures at Winchester, in the 12th century, in which are two paintings which are purely Italian and of more than ordinary excellence.

In the majority of the extant Italian miniatures of the 14th century the influence of the great artists of the Florentine school is manifest. The peculiar treatment of flesh tints, painted in body colour over a foundation of olive-green, and the peculiar vermilion and other colours which need be but once seen to be ever afterwards recognized as belonging to this school, are constantly present. The figures are generally rather shortened and the drapery carried in straight folds, very different characteristics from the swaying figures and flowing drapery of the English and French artists of the same period. The ornamentation which accompanied this style of miniature generally consists of heavy scrolls and foliated or feather-like pendants from the initial letters, with spots of gold set here and there in the border. There are also extant some examples of a most beautiful kind of ornamentation which appears to have originated in central Italy, and which seems to partake of the qualities of both the styles of Italian art of which we have been speaking, combining

the drawing of the Florentine school with a lighter colouring which may have been suggested by the Lombardic.

Of native Spanish miniature art little can be said. In the Visigothic MSS. of the early Middle Ages there is no ornament beyond roughly coloured initial letters and some barbaric figure drawing. A little later, however, we get some indication of national peculiarities in the MSS. of the 10th, 11th, and 12th centuries. Here there appear miniatures, stiff and rude in their drawing, but exhibiting the unmistakable Spanish predilection for sombre colours,—dusky reds and yellows and even black entering largely into the compositions.

The materials at our disposal of the 10th, 11th, and 12th centuries show the gradual development in France and western Germany of a fine free-hand drawing which was encouraged by the proportionately increasing size of books. Both in outline and colour the fully developed miniatures of the 12th century are on a grand scale; and initial letters formed of scrolls and interlacings assume the same proportions. The figure drawing of this time is frequently of great excellence, the limbs being well-proportioned; care is also bestowed upon the arrangement of the drapery, which is made to follow the shape and, as it were, to cling to the body.

But the great revulsion from the broad effects and bold grandeur of the 12th century to the exact details and careful finish of the 13th century is nowhere more striking than in miniature painting in MSS. With the opening of the new period we enter on a new world of ideas. Large books generally disappear to give place to smaller ones; minute writing supersedes the large hand; and miniatures appear in circumscribed spaces in the interior of initial letters. The combination of the miniature with the initial brings it into close connexion with the ornamental border, which develops *pari passu* with the growth of the miniature and by degrees assumes the same national and distinctive characteristics. Burnished gold was now also freely used, tending to give the miniature a more decorative character than formerly. In England, northern France, and the Netherlands the style of miniature painting of this period was much the same in character; and it is often difficult to decide from which of these countries a MS. is derived. English work, however, may be often distinguished by its lighter colouring, while deeper and more brilliant hues and a peculiar reddish or copper tinge in the gold marks French origin. The drawing of the Flemish artists was scarcely so good, the outlines being frequently heavy and the colours rather dull. Of the Rhenish or Cologne school examples are more scarce; but they generally show greater contrasts in the colours, which, though brilliant, are not so pleasing. As the century advanced, and particularly at its close, national distinctions became more defined. English artists paid more attention to graceful drawing and depended less upon colour. In some of their best productions they are satisfied with slightly tinting the figures, finding room in the backgrounds for display of brilliant colours and gilding. In France the drawing, though exact, is hardly so graceful, and colour plays a more important part. From the 13th to the middle of the 15th century great decorative effect is obtained by the introduction of diapered or other highly ornamented backgrounds. Of landscape, properly so called, there is but little, a conventional hill or tree being often taken as sufficient indication. Borders begin in the 13th century in the form of simple pendants from the initial letters, terminating in simple buds or cusps. But once arrived fairly in the 14th century, a rapid development in all parts of the decoration of MSS. takes place. There is greater freedom in the drawing; the borders begin to throw out branches and the bud expands into leaf. This is the best period of English miniature painting, many of the fine MSS. of this century which are preserved in the public libraries bearing witness to the skill and delicate touch of native artists. In France the decoration of MSS. received a great impetus from the patronage of King John and Charles V., of whose famous libraries many handsome volumes are still to be seen; and later in the century the duke of Berri carried on the same good work.

With regard to miniature art in Germany there are so few examples to guide us that little can be said. Most of them are rough in both drawing and colouring; and in the few remaining specimens of really good work foreign influence is distinctly seen. In the west the art of France and Flanders, and in the south that of Italy, are predominant. Perhaps the finest MS. of this southern style to be seen in England is a Psalter belonging to Lord Ashburnham, which was probably executed in the 14th century at Prague, and is full of miniatures which in drawing and colouring follow the Italian school.

When we enter the 15th century we find great changes in both the great English and French schools. In England the graceful drawing of the previous century has disappeared. At first, however, some beautiful examples of purely native work were produced, and still remain to excite our admiration. Probably the most perfect of these MSS. are the Sherborne Missal belonging to the duke of Northumberland, and a very beautiful volume, a Book of Hours, in the library of Lord Ashburnham. The care bestowed upon the modelling of the features is particularly noticeable in English work of this period. In decoration the border of the 14th century had by this time grown to a solid frame surrounding the page; but now another form of most effective ornament was also used, consisting of twisted feather-like scrolls brightly coloured and gilt. As the century advanced native English work died out, and French and then Flemish influence stepped in.

In France immense activity was shown all through the 15th century in the illumination and illustration of books of all kinds, sacred and profane; and it is in the MSS. of that country, and, a little later, in those of the Low Countries, that we can most exactly watch the transition from mediæval to modern painting. Early in the century there were executed in France some of the most famous MSS. which have descended to us. In these the colouring is most brilliant, the figure drawing fairly exact; and the landscape begins to develop. The border has grown from the branching pendant to a framework of golden sprays or of conventional and realistic leafage and flowers. Towards the middle of the century the diaper disappears for ever, and the landscape is a recognized part of the miniature; but perspective is still at fault, and the mystery of the horizon is not solved until the century is well advanced. And now Flemish art, which had long lain dormant, sprang into rivalry with its French sister, under the stimulus given to it by the Van Eycks, and the struggle was carried on, but unequally, through the rest of the century. French art gradually deteriorates; the miniatures become flat and hard; nor are these defects compensated for by the meretricious practice of heightening the colours by profusely touching them with gold. The Flemish artists, on the other hand, went on improving in depth and softness of colouring, and brought miniature painting to rare perfection. The borders also which they introduced gave scope for the study of natural objects. Flowers, insects, birds, and jewels were painted in detached groups on a solid framework of colour surrounding the page.

But if, as the 15th century drew to its close, the Flemings had outstripped their French rivals, they had now more powerful antagonists to contend with. The Italians had been advancing with rapid strides towards the glories of

the Renaissance. Early in the century there arose a taste for older models. As, for their writing and afterwards for their printing, they went back to the 11th and 12th centuries for their standards, so they adopted again the interlacing designs of the Lombardic school for their ornament, and produced beautiful borders of twining patterns relieved by colour; or they took natural objects for their models, and painted borders of delicate flowers made still more brilliant with clustering stars of gold. Later, they drew from the ancient classical designs inspiration for the wonderful borders of arabesques, medallions, griffins, human forms, antique objects, &c., which they brought to such perfection early in the next century. Their miniatures rose to the rank of exquisitely finished pictures, and were executed by some of the best artists working under the patronage of such great houses as those of Sforza and Medici.

Here then, having advanced to the threshold of the domain of modern painting, we leave these two great schools of miniaturists in possession of the west of Europe. The Flemings had the wider field; they were wanderers from home; and their works are scattered through many lands, from England in the north to Spain in the south. But Italian art had greater inherent strength, and will always hold the first rank. To instance a few of the more famous MSS. of this closing period of miniature painting: the Breviary of Isabella the Catholic, in the British Museum, is a masterpiece of Flemish art produced in Spain; the Grimani Breviary at Venice is another fine example of the same school. Some beautiful Italian miniatures (executed for Leo X. and others) were in the collection lately sold by the duke of Hamilton. The earl of Ashburnham possesses a most delicately illuminated Book of Hours written for Lorenzo dei Medici by the famous scribe Sinibaldo in 1485, as well as a MS. to which Perugino and his contemporaries contributed paintings. And in one MS., a Book of Hours belonging to Mr Malcolm of Poltalloch, are gathered some of the best miniatures of both schools, viz., a series of exquisite paintings by Milanese artists supplemented by later ones of the finest Flemish type. (E. M. T.)

MINIMS. See FRANCIS (ST) OF PAOLA, vol. ix. p. 695.

MINING

THE art of mining consists of those processes by which useful minerals are obtained from the earth's crust. This definition is wider than what is popularly known as mining, for it includes not only underground excavations but also open workings; at the same time it excludes underground workings which are simply used for passages, such as railway tunnels and sewers, and galleries for military purposes. We must remark also that the word "mine," or its equivalent in other languages, varies in signification in different countries on account of legal enactments or decisions which define it. Thus, in France and Belgium, the workings for mineral are classified by the law of 1810, according to the nature of the substance wrought, into *mines, minières, et carrières*. In the United Kingdom, on the contrary, it is the nature of the excavation which decides the question for certain legislative purposes, and the term mine is restricted to workings which are carried on underground by artificial light. The consequence is that what is merely an underground stone quarry in France becomes a true mine in England, whilst the open workings for iron ore, such as exist in Northamptonshire, would be true mines under the French law. It is necessary, therefore, in an article on mining, to go beyond the English legal definition of a mine, and include the methods of working minerals in excavations open to daylight as well as in those which are purely subterranean. Furthermore, as it is customary for the miner to cleanse his ore to a greater or less extent before selling it to the smelter, we shall treat, under the head of mining, those processes which are commonly known as the dressing or mechanical preparation of ores; and, finally, a few remarks will be made concerning legislation affecting mines in the United Kingdom, accidents in mines, and the production of the useful minerals in various parts of the globe.

The subject therefore will be dealt with as follows:—

1. Manner in which the useful minerals occur in the earth's crust, viz., tabular deposits and masses; faults or dislocations.
2. Prospecting, or search for mineral.
3. Boring with rods and ropes; diamond drill.
4. Breaking ground; tools employed; blasting by various methods; machine drills; driving levels and sinking shafts.
5. Principles of employment of mining labour.
6. Means of securing excavations by timber or masonry.
7. Exploitation, or the working away of strata or veins.
8. Carriage or transport of minerals through underground roads.
9. Winding, or raising in the shafts, with the machinery and apparatus required.
10. Drainage of mines, adit-levels, pumps, pumping engines.
11. Ventilation and lighting of mines.
12. Means of descending into and ascending from mines.
13. Dressing or mechanical preparation of minerals.
14. Recent legislation affecting mines in the United Kingdom.
15. Accidents in mines.
16. Useful minerals produced in various parts of the globe.

1. *Manner in which the Useful Minerals Occur.*—The repositories of the useful minerals may be classified according to their shape as (A) tabular deposits, and (B) masses.

A. *Tabular Deposits.*—These are deposits which have a more or less flattened or sheet-like form. They may be divided, according to their origin, into (1) beds or strata, and (2) mineral veins or lodes.

(1) *Beds.*—Geology teaches us that a large proportion of the rocks met with at the surface of the earth consist of substances arranged in distinct layers, owing to the fact that these rocks have been formed at the bottom of seas, lakes, or rivers by the gradual deposition of sediment, by precipitation from solutions, and by the growth or accumulation of animal and vegetable organisms. If any one of these layers consists of a useful mineral, or contains enough to make it valuable, we say that we have a deposit in the form of a bed, stratum, or seam. Of course the most important of all bedded or stratified deposits is coal, but, in addition, we have beds of anthracite, lignite, iron ore, especially in the Oolitic rocks, cupriferous shale, lead-bearing sandstone, silver-bearing sandstone, diamond-, gold-, and tin-bearing gravels, to say nothing of sulphur, rock-salt, clays, various kinds of stone, such as limestone and gypsum, oil-shale, alum-shale, and slate.

The characteristic feature of a bed is that it is a member of a series of stratified rocks; the layer above it is called the *roof* of the deposit, and the one below it is the *floor*. Its *thickness* is the distance from the roof to the floor at right angles to the planes of stratification; its *dip* is the

inclination downwards measured from the horizontal; its *strike* is the direction of a horizontal line drawn in the middle plane.

The thickness of beds that are worked varies within very wide limits. Whilst the thickness of certain workable beds of coal is only 1 foot, and that of the Mansfeld cupriferous shale only 10 to 20 inches, we find on the other hand one of the beds of lead-bearing sandstone at Mechernich no less than 85 feet thick, and beds of slate far exceeding that thickness. It must not be supposed, however, that the thickness of a bed necessarily remains uniform. Occasionally this is the case over a very large area; but frequently the thickness varies, and the bed may dwindle away gradually, or increase in size, or become divided into two owing to the appearance of a parting of valueless rock. Fig. 1 shows beds of shale, limestone, iron ore, and sandstone. Any one of these beds may be valuable enough to be worked.

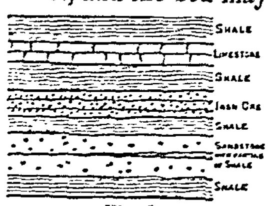


Fig. 1.

Mineral veins. (2) *Mineral Veins or Lodes.*—Veins or lodes are tabular or sheet-like deposits of mineral which have been formed since the rocks by which they are surrounded; they differ, therefore, by their subsequent origin from beds, which, as just stated, are of contemporaneous origin with the enclosing rocks (although of course cases occur in which the deposit is lying unconformably upon very much older strata, or is covered unconformably by very much younger strata). It is necessary to explain that the term "vein" in this definition is used in a more restricted sense than is sometimes customary among miners, who speak of *veins* of coal, clay-ironstone, and slate, which geologically are true beds. They see a band of valuable mineral or rock, and, careless of its origin, call it metaphorically a vein or seam. On the other hand, the definition is broader than that which prevails among some geologists, who would confine the term vein to deposits occupying spaces formed by fissures.

The term "lode" was defined in 1877 by Mr Justice Field in the celebrated Eureka *v.* Richmond case as follows:—"We are of opinion, therefore, that the term, as used in the Acts of Congress, is applicable to any zone or belt of mineralized rock lying within boundaries clearly separating it from the neighbouring rocks." This interpretation seems suitable for the peculiar mining tenure of the United States, where the discoverer of a vein or lode can obtain a mining claim of 500 yards in length along the lode. It protects the prospector, whose object is to obtain a secure title, the mode of origin of the deposit being a matter of small importance to him so long as it is worth working. In many cases also it would be impossible to decide upon the mode of origin until workings had progressed considerably, and even then there would be room for disputes.

No doubt a very large number of mineral veins are simply the contents of fissures; others are bands of rock impregnated with ore adjacent to fissures or planes of separation; others, again, have been formed by the more or less complete replacement of the constituents of the original rock by particles of ore.

Veins may occur in igneous or in sedimentary rocks, and in the latter they frequently cut across the planes of stratification.

Like a bed, a vein has its dip and strike; but, as the dip of veins is generally great, the inclination is usually measured from the vertical, and is then spoken of as the *underlie* or *hade*. The bounding planes of a vein are called the *walls* or *cheeks*, and they are frequently smooth and striated, showing that one side must have slid against the other. The upper wall is known as the *hanging wall*, the lower one as the *foot wall*. The width of a vein is measured at right angles to the walls.

A typical example of a fissure-vein is shown in fig. 2, representing a lead lode in slate at Wheal Mary Ann mine[1] in Cornwall. It is evident that a fissure in the surrounding slate has here been filled up by the successive deposition of bands of mineral on both sides.

A large proportion of the contents of a lode may consist of fragments of the walls that have fallen into the original fissure, and these are often tightly cemented together by minerals that have been introduced subsequently. The horizontal section of part of the Comstock lode[2] (Plate IV.) shows much "country" rock enclosed within the walls.

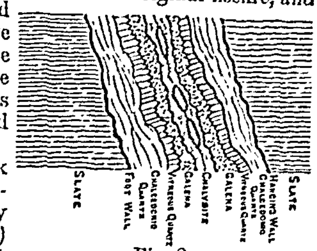


Fig. 2.

Where a lode consists of rock impregnated with ore, the mineralized part may fade away gradually into the surrounding rock (*country*) without there being any distinct wall, as shown in *fig.* 3, which is an illustration taken from the Great Flat Lode[3] near Redruth in Cornwall.

The celebrated Ruby Hill deposit in the Eureka district, Nevada, is a mineralized zone of dolomitic limestone varying in width from a few inches to 450 feet, and having a mean width of 250 feet. It contains numerous irregular ore-bodies, which consist mainly of highly ferruginous carbonate of lead, rich in silver and gold. This mineralized limestone band, long called a lode by miners, has been determined by the decision just mentioned to be a lode in the eyes of the law.

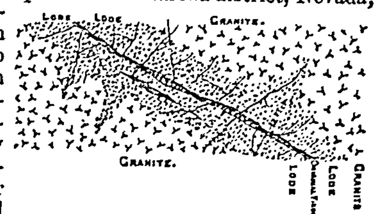


Fig. 3.

Veins often continue for a great distance along their strike. The Van lode in Montgomeryshire is known for a length of 9 miles, whilst the Great Quartz Vein in California has been traced for a distance of no less than 80 miles. Veins are of less uniform productiveness than beds, and are rarely worth working throughout. Rich portions alternate with poor or worthless portions. The rich parts have received various names according to the forms they assume: *fig.* 4 represents a longitudinal section along the strike (*course*) of a lode, and the stippled parts are ore-bodies; B, B, B are *bunches*; A is a large bunch or *course of ore*; when an ore-body forms a sort of continuous column we have a *shoot*, and ore-bodies which on being excavated leave chimney-like openings are called *pipes* (fig. 4, C). In the United States the Spanish word *bonanza*, literally meaning "fair weather" or "prosperity," is frequently used for a rich body of ore.

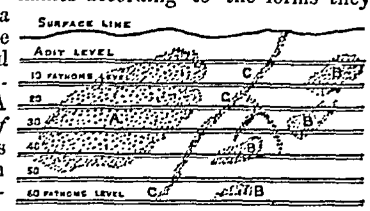


Fig. 4.

The richness of veins is dependent in many cases upon the nature of the adjacent rock (*country*), upon the underlie, and upon the strike, variations in any one of these three elements being often sufficient to cause a decided change of productiveness.

Various theories have been formed concerning the origin of mineral veins. Some geologists suppose that the minerals now constituting the veins have been dissolved out of the adjacent rocks and re-deposited in the vein cavity; others, on the contrary, believe that the ores have been brought up from great depths by mineral springs. In all probability both theories are correct, some lodes having been formed by the former process and some by the latter; and, furthermore, other lodes appear to owe their origin to a gradual substitution of valuable minerals in the place of some of the constituents of a worthless rock. One of the most important contributions to the science of ore-deposits of late years has been the discovery by Professor F. Sandberger of small quantities of silver, lead, copper, nickel, cobalt, bismuth, arsenic, antimony, and tin in silicates, such as olivine, augite, hornblende, and mica, which are constituents of igneous rocks. He therefore regards these rocks as the sources from which lodes have derived their riches.

Masses. B. *Masses.*—These are deposits of mineral, often of irregular shapes, which cannot be distinctly recognized as beds or veins. Such, for instance, are the red hæmatite

[1] C. Le Neve Foster, "Remarks on the Lode at Wheal Mary Ann, Menheniot," *Trans. Roy. Geol. Soc. Cornwall*, vol. ix. p. 153.

[2] James D. Hague, in *United States Geological Exploration of the Fortieth Parallel*, vol. iii., "Mining Industry," Washington, 1870, Atlas, plate 11.

[3] C. Le Neve Foster, "On the Great Flat Lode south of Redruth and Camborne, and on some other Tin Deposits formed by the Alteration of Granite," *Quart. Jour. Geol. Soc.*, vol. xxxiv. p. 644.

deposits of the Ulverston district (fig. 5[1]) and the brown hæmatite deposits (*churns*) of the Forest of Dean, which

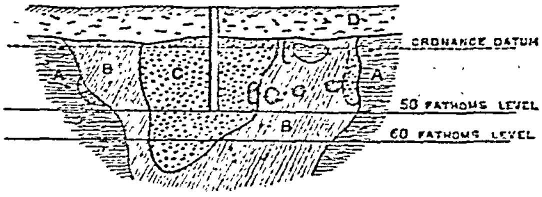


Fig. 5.—Vertical Section, Roanhead Mine. A, Mountain Limestone; B, red hæmatite; C, sand and clay; D, gravel. Scale $\frac{1}{3000}$.

occupy irregular cavities in the Mountain Limestone. These may have been formed by the percolation of water bringing down iron in solution from overlying Triassic rocks. Other examples of masses are the calamine deposits of Altenberg[2] (fig. 6), Sardinia, and Lombardy, the iron ore deposits in Missouri, such as Iron Mountain and Pilot Knob, the huge upright "necks" or "pipes" of diamantiferous rock in South Africa, and the granite decomposed *in situ* worked for china clay in Cornwall.

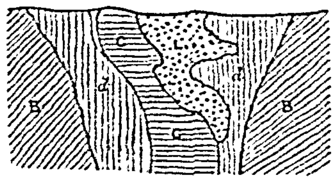


Fig. 6.—Vertical Section, Altenberg. B, slate; *d*, dolomite; C, calamine; L, clay.

Under this head also are included by most authors the so-called "stockworks" or "reticulated masses," names applied to masses of sedimentary or igneous rock which are penetrated by so many little mineral veins as to make the whole worth excavating.

It must be understood that we cannot expect nature to make distinct lines of demarcation between the different kinds of deposits. Though we may be able to see clearly that a seam of coal is contemporaneous with the enclosing rocks, and that a vein intersecting beds of shale and sandstone was formed subsequently, cases frequently occur where the origin of the mineral is uncertain. For example, we have the lead-bearing sandstone of Mechernich and the silver-bearing sandstone of Utah. The grains of sand are of sedimentary origin; but opinions differ as to whether the lead and silver respectively were deposited with the sand or were introduced subsequently by solutions percolating through the beds. In the case of the well-known bed of Cleveland ironstone, Dr Sorby considers that the iron was "derived partly from mechanical deposition and partly from subsequent chemical replacement of the originally deposited carbonate of lime."[3] Furthermore, a bed may be so folded and contracted as to lose its original sheet-like form in places and assume the shape of an irregular mass. This may happen even with a coal seam.[4]

Faults. All kinds of deposits are subject not only to irregularities of origin dependent upon their mode of formation but also to dislocations or shiftings known as faults, heaves, or throws.

We will take the case of a bed (fig. 7). AB is a seam which ends off suddenly at B, whilst the continuation is found at a lower level at CD. The bed was evidently once continuous; but a fracture took place along the line XY followed by a displacement. As a rule

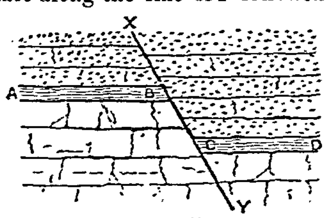


Fig. 7.

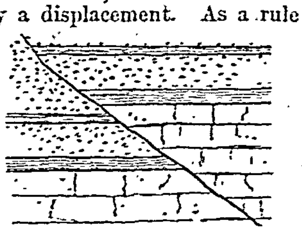


Fig. 8.

the portion of rock on the hanging-wall side of a fault appears to have slid downwards, but occasionally this is not so, and we have a reversed fault (fig. 8). It is very evident, in some cases, that the motion took place, not along the line of greatest dip, but in a diagonal direction, causing a displacement sideways as well as downwards. Nevertheless, where beds or veins are not horizontal, a mere shift along the line of dip is sufficient to cause an apparent heave sideways. This will be understood from fig. 9. Let AB and CD represent two portions of a lode dislocated by the fault EF. The point B′ corresponded originally with B, and the dislocation was caused by a simple sliding of B′ along the line of dip BB′. An instance of the complication caused by a succession of faults is shown in fig. 10.[5]

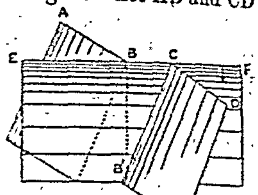


Fig. 9.

2. *Prospecting, or Search for Mineral.*—The object of the prospector is to discover valuable deposits of mineral. This search is beset with many difficulties: the outcrops of Prospecting.

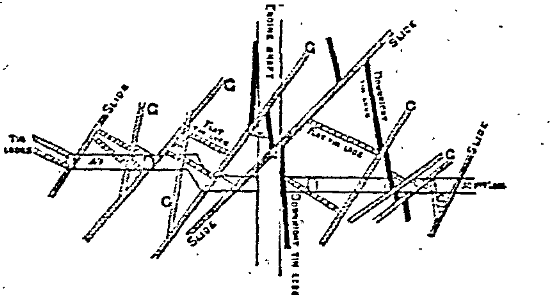


Fig. 10.—Vertical Section, Penhalls Mine, Cornwall. G, G, G, small veins called *gossans* in the St Agnes district.

mineral deposits are frequently hidden by soil; the nature of the deposit itself is generally entirely changed near the surface; and, in addition to this, the explorer may have to pursue his work in trackless forests far away from any settlements.

The prospector seeks for natural sections of the rocks, such as occur in cliffs or in river valleys and their tributary gullies and gorges; he examines the materials constituting the river-beds, often digging up and washing portions in a pan, in order to ascertain whether they contain traces of the heavy ores or metals. If, while prospecting in a valley, he discovers stones that have the appearance of having once belonged to veins, he endeavours to trace them to their source, and is perhaps rewarded by finding similar fragments, but less water-worn, as he goes up the stream; further on he may come upon large blocks of veinstuff lying about, and finally find the vein itself laid bare in a gorge, or at the bottom of a brook, or possibly projecting above the soil in the form of huge crags of quartz. Thus at the Great Western quicksilver mine in California the outcrop of the vein appears as a dike over 100 feet wide, and having precipitous sides in places 75 feet high.[6] Loose pieces of veinstuff found lying about are known in Cornwall as shoad-stones, and *shoading* is the term given to the process of tracking them to the parent lode.

The upper portion of a deposit is frequently much altered by atmospheric agencies, and bears little resemblance to the undecomposed bed or vein which will eventually be met with at a greater or lesser depth. The principal difference consists in the change of sulphides into oxides or oxidized compounds. Thus iron pyrites, which is such a common constituent of mineral veins, is converted into hydrated oxide of iron, and a vein originally consisting largely of iron pyrites and quartz now becomes a cindery mixture of quartz and ochre, known in Cornwall as *gossan*. This gossan, or *iron hat*, may often furnish important indications concerning the nature of the lode itself, because such minerals as pyromorphite or cerussite point to the existence of galena, whilst melaconite, cuprite, malachite, and azurite are the forerunners of chalcopyrite or copper glance. The gossan itself may contain a sufficient quantity of valuable ores to be worth working.

The seams containing native sulphur in Sicily often show no trace of that element immediately at the surface, as the sulphur-bearing limestone weathers into a soft white granular or pulverulent

[1] Fr. Moritz Wolff, "Beschreibung der Rotheisenerzlagerstätten von West Cumberland und North Lancashire," *Stahl und Eisen*, 2 Jahrgang, No. 12, plate vi.

[2] M. Braun, *Zeitschr. d. d. geol. Gesellsch.*, 1857, vol. ix.; and A. [Gr]oddeck, *Die Lehre von den Lagerstätten der Erze*, Leipsic, ... 242.

ous m... shafts.

5. Princi... *Jour. Geol. Soc.*, vol. xxxv. (1879), p. 85, Anniversary ... resident.

6. Means of

Lectures on Mining, vol. i. p. 63, and Atlas, plate

[5] J. W. Pike, "On some remarkable *heaves* or *throws* in Penhalls Mine," *Quart. Jour. Geol. Soc.*, vol. xxii. p. 537.

[6] Luther Wagoner, "The Geology of the Quicksilver Mines of California," *Engineering and Mining Journal*, vol. xxxiv. p. 334.

variety of gypsum, called *briscale* by the miners, and considered by them as affording important indications concerning the bed itself.[1]

Other signs of mineral deposits are given by springs and by certain plants dependent upon the deposit or its associated minerals for part of their nourishment. The appearance of the so-called lode-lights may be explained by the production of phosphoretted hydrogen from the action of organic matter and water upon phosphates, which are so common in the upper parts of mineral veins; and one hears also of differences in the appearance of the vegetation along the line of the deposit, of places where snow will not lie in winter, and of vapours hanging over the ground. Though some writers refuse to put any value upon these indications, they should not be entirely overlooked, because the outcrop of a lode, of different nature and texture to the surrounding rocks, and which is generally a channel for water, may readily cause the phenomena just mentioned. Where the surface is cultivated and the natural springs are tapped by adit-levels or other mine-workings, these appearances cannot be looked for to any great extent. With one special mineral, magnetic iron, the position of the deposit may be traced out with some degree of accuracy with a dipping needle; this is used in Sweden.

After having acquired an idea of the position of a vein or seam by some of the surface indications just mentioned, it is necessary, before attacking it by shafts or levels, to obtain more certain data concerning it. In the case of mineral veins, trenches are dug at right angles to the supposed strike; and, when the upper part of the deposit has been cut in several places, its general course and dip can be determined sufficiently for the purpose of arranging the future workings. These trenches are called "costean pits"; in some cases, instead of a trench, a pit is sunk a short distance and a little tunnel driven out.

Where the mineral to be wrought occurs as a bed or mass, the process of boring is resorted to, and indeed this method is also applied in the case of veins, especially in the United States. Boring is a work of such importance that it deserves to be treated under a separate heading.

Boring.

3. *Boring with Rods and Ropes—Diamond Drills.*—The object of boring is to reach a deposit by a small hole and ascertain its nature, its depth from the surface, thickness, dip, and strike. Bore-holes are also used for obtaining water, brine, and petroleum, which either rise to the surface or have to be pumped up from a certain depth, and finally for tapping water in old workings or for effecting ventilation. The methods of boring may be classified as follows:—(1) boring with the rod; (2) boring with the rope; (3) boring with the diamond drill.

Boring with rods.

In the first method tools for cutting and removing the rock are fixed to rods, which are lengthened as the hole increases in depth, and which are worked by hand or by machinery at the surface. Where the ground is soft, such as sand or clay, tools like augers can be employed; but in harder ground it becomes necessary to have recourse to percussion; various forms of chisel are used, the simplest being made of the shape shown in fig. 11.[2] The rods generally consist of bars of square iron, from 1 inch to 2 inches on the side. The length of each rod depends upon the height of the tower, derrick, or shears erected above the bore-hole, which should be an exact multiple of the individual parts. These are made in lengths of 15 to 30 or rarely 40 feet, and with a suitable tower it is possible to detach or attach two or three lengths at a time, instead of having to make or unmake every joint. The mode of connexion usually preferred is by a screw joint as shown in fig. 12; care is taken to have all the joints exactly alike, so that any two bars can be screwed together. In order to

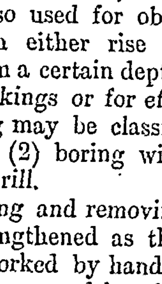


Fig. 11.—Chisels.

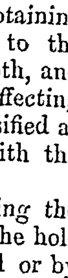


Fig. 12.

diminish the weight of the rods, which becomes considerable in deep holes, wood has sometimes been employed. The rods are connected by male and female screws attached to the rods by sockets of sheet iron, or by a fork-like arrangement. At the surface a head is screwed to the uppermost rod by which the rods can be lifted, and they are turned by means of cross-bars called tillers.

When the depth is small the rods are lifted by hand and then allowed to drop, being turned slightly at each lift so that the cutting chisel may strike a new place each time. For greater depths a lever has to be employed, the rods being suspended at one end, whilst the other end can be pressed down by men using their hands or feet. The spring pole is another arrangement, in which the elasticity of a long pole is made use of for lifting the rod at each stroke. The length of the stroke can be maintained the same while the bore-hole is deepened by means of a screw in a swivel-head at the top of the rod.

With deep holes, and especially those of large diameter, steam machinery has to be employed for working the rod; the engine may be direct-acting and stand immediately above the bore-hole, but a commoner arrangement is to employ a single-acting cylinder working a beam. Occasionally also the beam is actuated by a connecting-rod worked by a crank.

The actual boring machinery has now been described, and the mere boring appears to be a very simple matter, consisting only in lifting the rod a little and allowing it to drop, the rod being turned slightly before each stroke. Nevertheless the process of putting down a bore-hole is not so simple as it seems, for there are numerous indispensable accessory operations which take up much time. In the first place the débris have to be removed, and in order to effect this the rods must be drawn up, the swivel-head is disconnected and a cap screwed on. A length of rods is now drawn up by a hand or steam windlass and disconnected. It is well to have as many caps as there are lengths to be drawn up, and then each length can be suspended in the house. Sometimes a *grip* which catches the rod at the bulging joint is used instead of a cap. The next operation consists in lowering by means of a rope the *shell-pump* or *sludger*, which is a hollow cylinder with a clack or a ball-valve (fig. 13). It is worked up and down a little till it is filled, and it is then drawn up and emptied at the surface. The operation is repeated, if necessary, and the boring is resumed with the rod.

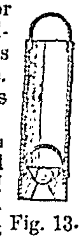


Fig. 13.

Occasionally a bore-hole has to be widened slightly with a tool called a *reamer*. Soft beds may have to be bored through with a *wimble*; and, unless the rocks are hard and firm, the hole has to be lined with a tube, generally of sheet-iron. Accidents may occur, causing an immense amount of trouble, such as the breaking of rods or chisel, and many ingenious implements have been devised for seizing the broken rod or the fragments of tools which prevent further progress with the work.

In boring at considerable depths, the weight of the rod becomes so great that much vibration ensues when the mass is suddenly arrested by the chisel striking against the bottom of the hole. Various devices have been contrived for overcoming this difficulty and producing a tool which will act independently of the rod. One of the best-known arrangements is the free-falling tool invented by Kind (fig. 14).[3] The head of the actual boring-rod is held by a click or grapple; when the main rod descends, the resistance of the water in the hole slightly stops the sliding disk D, the jaws J, J open, the head is disengaged, and the boring part falls and strikes the bottom without any injurious vibrations being communicated to the main rod. When this descends farther the head is caught again by the click. Special tools also are used for cutting an annular groove at the bottom of a bore-hole and breaking off the core, which is then brought up, with certain precautions, so as to show the nature and dip of the strata traversed.


Fig. 14.

Boring with rope.

In order to obviate the great loss of time which ensues from connecting and disconnecting long lengths of rods, recourse may be had to boring *with the rope*. In this method, known as the Chinese method, the chisel is worked by a rope in the same manner as the sludger already described. Messrs Mather and Platt of Manchester have long used with success, in many parts of England and various other countries, a system of boring by means of a flat hempen rope.

The most important modification of late years in the

[1] Lorenzo Parodi, *Sull' Estrazione dello Solfo in Sicilia*, 1873, pp. 7 and 24.

[2] Serlo, *Leitfaden zur Bergbaukunde*, Berlin, 1878, p. 59.

[3] J. Callon, *Lectures on Mining*, vol. i., Atlas, plate ix. fig. 52.

Diamond drill.

process of making bore-holes is the introduction of the diamond drill. The working part of the drill consists of the so-called crown, which is a short piece of tube made of cast steel, at one end of which a number of black diamonds are fastened into small cavities (fig. 15). The crown is screwed on to wrought-iron pipes, which constitute the boring rod. Machinery at the surface causes the rod to rotate, and the result is the cutting of an annular groove at the bottom of the hole, leaving a core, which, breaking off from time to time, is caught by a little shoulder, and brought up to the surface with the rod. In places where it is not necessary to make any verification of the rocks traversed, the crown is arranged with diamonds in the centre also. The débris, in either case, are washed away by a stream of water, which is forced down the tube and flows up the sides of the hole. With this system a bore-hole can be deepened continuously at a speed altogether unattainable by the other methods, which require stoppages for cleaning out. It has the further advantage of making it possible to drill holes in any direction; and prospecting diamond drills are constantly used with much success inside many metal mines, especially in the United States.

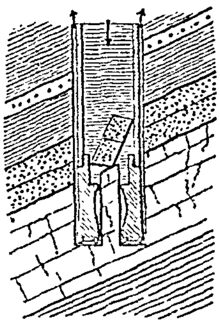


FIG. 15.—Diamond Drill.

Fig. 16[1] shows the Little Champion Rock-Drill, which is largely employed in the Lake Superior district for prospecting. It can be used above or below ground. Two inclined cylinders drive a horizontal crank shaft, which works bevel gear, causing the drill to revolve. At the same time a countershaft is likewise set in motion, and this effects the advance of the drill by gearing driving the feed-screw; as there are three kinds of gearing, the speed can be varied at pleasure. The feed-screw and its connexions are carried by a swivel-head, and this can be turned so as to drill holes at an angle. The drum shown above the cylinders is used for hoisting out the drill-rods by a rope. The rods are lap-welded iron tubes $1\frac{5}{8}$ inches in diameter, fitted with a bayonet joint.

Another light portable prospecting drill for underground work is

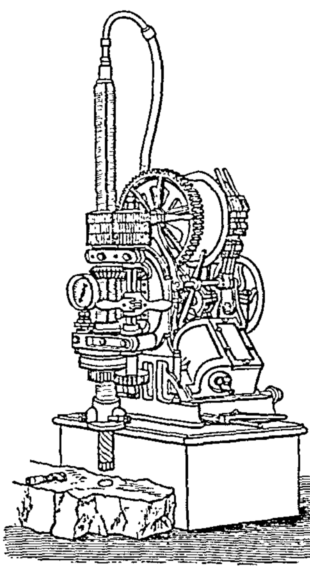


FIG. 16.—Little Champion Rock-Drill.

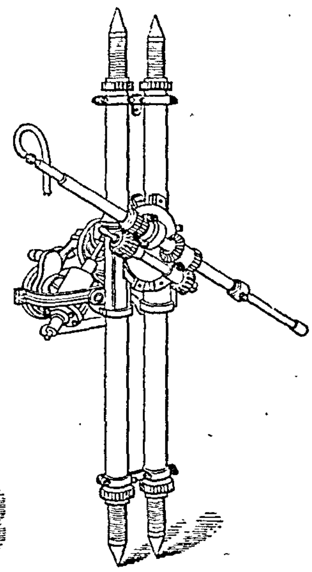


Fig. 17.

represented in fig. 17.[2] It is intended for drilling holes $1\frac{1}{4}$ inches in diameter to a depth of 150 feet. The cores which it yields are $\frac{7}{8}$ inch in diameter. It has double oscillating cylinders $3\frac{1}{2}$ inches in diameter with $3\frac{1}{2}$ inches stroke, which are run up to a speed of 800 revolutions. The drill can be set to bore in any direction by turning the swivel-head on which it is carried.

The larger rock-drill used by the American Diamond Rock Boring Company for putting down holes to a depth of 2000 feet consists of a 20 horse-power boiler with two oscillating 6-inch cylinders and the necessary gearing for working the drill, all mounted upon a carriage, so that the whole machine is readily moved from place to place. The feed is effected by gearing or by hydraulic pressure; a $2\frac{3}{4}$-inch crown is employed, leaving a 2-inch core. Each separate drill-rod is 10 feet long. The total weight of the machine is about 4 tons.

1 *Engineering and Mining Jour.*, vol. xxxiii. p. 119.
2 *Ibid.*, vol. xxxiii. p. 273.

4. *Breaking Ground—Tools Employed—Blasting by Various Methods—Machine Drills—Driving Levels and Sinking Shafts.*—The kind of ground in which mining excavations have to be carried on varies within the widest limits, from loose quicksands to rocks which are so hard that the best steel tools will scarcely touch them.

Tools.

Loose ground can be removed with the shovel; but in the special case of peat sharp spades are employed, which cut through the fibres and furnish lumps or sods of convenient form for drying and subsequent use as fuel. What is called *fair*, *soft*, or easy ground, such as clay, shale, decomposed clay-slate, and chalk, requires the use of the pick and the shovel. The pick is a tool of very variable form, according to the material operated on. Thus there are the navvy's pick, the single-pointed pick with a striking head at the other end called the poll-pick (fig. 18), and numerous varieties of the double-pointed pick (fig. 19), the special tool of the collier, but also largely used in metal mining. When the ground, though harder, is nevertheless "jointy," or traversed by many natural fissures, the wedge comes into play. The Cornish tool known as a *gad* is a pointed wedge (fig. 20). The so-called "pick and gad" work consists in breaking away the easy ground with the point of the pick, wedging off pieces with the gad driven in by a sledge or the poll of the pick, or prizing them off with the pick after they have been loosened by the gad. The Saxon gad is held on a little handle, and is struck with a hammer. It is used for wedging off pieces of jointy ground, and in former days even hard rocks were excavated by its aid. The process consisted in chipping out a series of parallel grooves and then chipping away the ridges left between the grooves. As a method of working this process is obsolete; but it is useful on a small scale for cutting recesses (*hitches*) for timber, for dressing the sides of levels or shafts before putting in dams, and for doing work in places where blasting might injure pumps or other machinery.

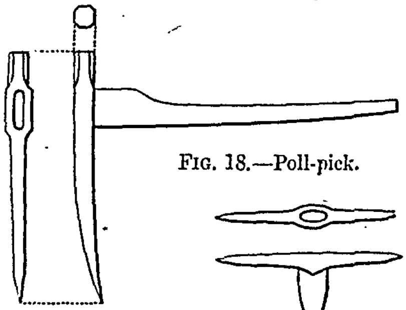


FIG. 18.—Poll-pick.

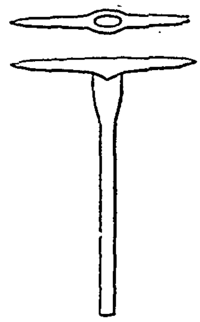


FIG. 19.—Double-pointed Pick.

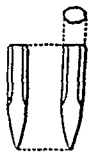


FIG. 20.—Gad.

We now come to hard ground; and in this class we have a large proportion of the rocks met with by the miner, such as slate of various kinds, hard grits and sandstone, limestone, the metamorphic schists, granite, and the contents of many mineral veins. Rocks of this kind are attacked by boring and blasting. The tools employed are the jumper, the borer or drill, the hammer, the sledge (*mallet*, Cornwall), the scraper and charger, the tamping bar or stemmer, in some places the pricker or needle, the claying bar, the crowbar, and finally the shovel for clearing away the broken rock.


Fig. 21.

The jumper (fig. 21) is merely a long bar of iron terminating in two chisel-like edges made of steel; generally there is a swelling in the middle, and sometimes the jumper tapers all the way from the middle to the edge or bit. The jumper is most commonly used when it is necessary to bore holes downwards, and is

largely employed in quarries; occasionally it is used in boring holes horizontally, as for instance in the salt mines of Cheshire. The jumper is held in the desired direction, lifted up, and thrust down; it is turned a little after each stroke.

However, the miner's tool is generally the borer proper, or drill (fig. 22), which is a bar of round or octagonal steel, usually from $\frac{7}{8}$ inch to $1\frac{1}{2}$ inches in diameter, with one end forged into a chisel-shaped edge, the exact shape and degree of sharpness varying according to the hardness of the rock. The hole is bored by striking the drill with a hammer or sledge and turning it after each blow. Boring is said to be single-handed if the miner holds the drill in one hand and strikes with the hammer in the other, whilst it is called double-handed when one man turns and another strikes. The hammers for single-handed boring usually vary in weight from 2 to 6 or 7 lb. The double-handed boring hammer, or sledge (fig. 23), weighs from 6 to 10 lb or more. If a hole is directed downwards, the miner pours in a little water and bores the hole wet. From time to time he draws out the sludge with the scraper, a little disk at the end of a metal rod, and he takes a fresh borer when the tool he is using has become blunt. The depth bored varies with the rock and the nature of the excavation; but in driving levels in the ordinary way the depth is commonly from 18 inches to 3 feet.

Fig. 22.

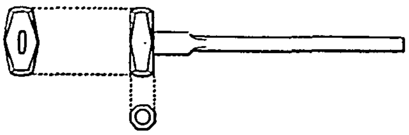


Fig. 23.—Sledge-Hammer.

Holes for blasting are sometimes bored by tools like carpenters' augers. One of the simplest, which is used in some French slate-mines, is very like a brace and bit, and the tool is kept pressed against the rock by means of a screw fixed in a frame resting on the ground.

The pricker, or needle, is a slender tapering rod of copper or bronze, with a ring at the large end. It is used for maintaining a hole in the *tamping* through which the charge can be fired. The use of needles made of iron is prohibited in many countries, on account of the danger of their striking sparks which might fire the charge. The tamping bar, or *stemmer*, is a rod of iron, copper, or bronze, or iron shod with copper, and it is used for ramming in dried clay, slate pounded up, or other fine material, upon the powder, and so creating a resistance sufficient to make the gases generated by the explosion of the charge rend the rock in the manner required. The claying bar is used for lining wet holes with clay, and so rendering them temporarily watertight.

Shovels vary much in different districts. In the south-west of England the long-handled shovel is preferred to the common one with a short handle; in Germany the ore or rubbish is frequently scraped into a tray with a sort of hoe.

Explosives.

In addition to these tools the miner requires an explosive, and a means of firing the charge at the bottom of the hole which will give him time to escape. Twenty years ago gunpowder was the only explosive in common use in mines, but at the present day its place has been taken to a very large extent by mixtures containing nitro-glycerin or gun-cotton. The powder used for blasting in mines usually contains less saltpetre than that which is employed for sporting or military purposes. The following is an analysis of mining powder by Captain Noble and Sir F. Abel:[1]—

Saltpetre	61·66	Oxygen	2·23
Potassium sulphate	0·12	Ash	0·59
,, chloride	0·14	Water	1·61
Sulphur	15·06		
Carbon	17·93		100·00
Hydrogen	0·66		

1 "On Fired Gunpowder," *Phil. Trans.*, 1880, p. 225.

Gunpowder compressed into cylinders of diameters suitable for bore-holes, and provided with a central hole for the insertion of the fuse, has lately been brought forward with some success.

Nitro-glycerin or glyceryl nitrate is a light-yellow oily liquid which is very sensitive to shocks; under the action of a fulminating cap it explodes with great violence. Its chemical composition is expressed by the formula $C_3H_5(NO_2)_3O_3$ or $(C_3H_5)3NO_3$; its specific gravity is 1·6. It has been found so dangerous that its use by itself has been given up; but on the other hand the mixture of nitro-glycerin and infusorial earth (*Kieselguhr*) called dynamite or giant powder is now one of the commonest explosives met with. It has the advantage over powder that it is far more powerful, that it may be used in wet holes or under water, that it is very effective even in ground full of "vughs" or cavities, and that it requires no hard tamping, which is always a source of danger. Its plasticity too enables it to fill the space at the bottom of a bore-hole, which is rarely a true cylinder, more completely than any solid cartridge can do. One disadvantage is that it has to be thawed in cold weather, and there is also the fact that occasionally the whole of a charge of dynamite fails to go off, and unnoticed remnants have exploded and caused serious and even fatal accidents when struck with the pick or borer. The danger is enhanced when the remnants have been left in contact with water, which causes a separation of the sensitive nitro-glycerin, so that even a blow upon the adjacent rock may lead to an accident if any of the explosive oil has leaked into cracks. The strongest dynamite contains about 75 per cent. of nitro-glycerin, the rest being kieselguhr. A newer explosive is blasting gelatin; it is made by mixing nitro-cotton with nitro-glycerin, until enough nitro-cotton has been dissolved to convert the nitro-glycerin into a jelly-like mass. The blasting gelatin in ordinary use contains no less than 93 per cent. of nitro-glycerin, with 7 per cent. of nitro-cotton, and its strength is very great.

Gun-cotton *per se* is not much in favour in ordinary mining; but mixed with some nitrate or mixture of nitrates, such as the nitrates of barium and potassium, and known as cotton powder, tonite, and potentite, it is employed extensively. Though not quite so powerful as dynamite, nitrated gun-cotton possesses the important advantage of not requiring to be thawed in cold weather. As in the case of dynamite, accidents have been caused by remnants of charges; and with both explosives it is necessary to examine carefully the bottoms of all holes after blasting, and to destroy any possible remnants by firing off a detonator in any bottom or "socket" which cannot with certainty be pronounced free from danger.

Safety-fuse.

The commonest method of firing a charge is by means of the *safety-fuse*, a cord containing a core of gunpowder introduced during the process of manufacture; it may be rendered waterproof by tar or gutta-percha.

In blasting in the ordinary way the charge of gunpowder is put in either loose or enclosed in a paper bag, and it is pressed down to the bottom of the hole with a wooden stick, whilst a piece of fuse also is inserted extending from the charge well beyond the hole. If the powder is loose the miner carefully wipes down the sides of the hole with a wet *swab stick* (a wooden rod with the fibres frayed at one end), or with a wisp of hay twisted round the scraper, in order to remove any loose grains adhering to the fuse or the sides of the hole, and then presses in a wad of hay or paper. A little fine tamping, often the dust from boring a dry hole, is now thrown in and rammed down with the wooden charging stick, and the same process is repeated, and when harder tamping is required the metal bar is brought into operation, until the hole is completely filled.

As the safety-fuse burns slowly, at the rate of about 2 or 3 feet a minute, the miner can secure ample time for retreat by taking a sufficient length. It is usual to ignite the fuse by a candle-end fixed under it by a piece of clay, and it takes a little time for the candle to burn through the fuse.

The old plan of firing a charge, which is still in use in many

places, consists in inserting the needle into the charge and then tamping up the hole. Care is taken to draw out the needle a little as the tamping proceeds, so as to prevent too much force being required for its final withdrawal. The small hole left in this way serves for the insertion of a straw, rush, or series of small quills, filled with fine powder, which like the fuse reaches from the charge to the outside. A short squib which shoots a stream of sparks down the needle hole is also used occasionally. The straw or squib is lighted by some kind of slow match, made either by dipping a cotton strand in melted sulphur or soaking a piece of paper or a lucifer in the tallow of a candle; touch-paper also is used.

Dynamite, blasting gelatin, gun-cotton, and cotton-powder are fired by the detonation of a fulminating cap. A long copper cap containing fulminate of mercury is fastened into the safety-fuse by squeezing with a pair of nippers, and is then inserted into a small cartridge of the explosive (*primer*), and placed above the rest of the charge. Fig. 24 shows a hole charged with two dynamite cartridges, a primer with cap, and filled up with water as tamping. Sometimes gun-cotton is fired by a small charge of powder above it.

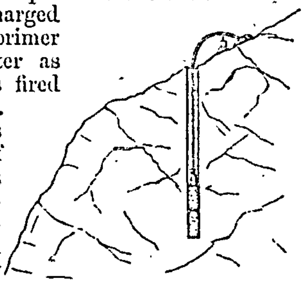


Fig. 24

Several substitutes for explosives have been tried with the object of getting rid of the flame, which is dangerous in collieries giving off fire-damp. Among these may be mentioned plugs of dry wood which swell when wetted, wedges worked by hydraulic pressure, cartridges containing compressed air at extremely high pressures, and lastly cartridges of compressed lime which expands when water is brought into it.

For the purpose of firing several holes simultaneously, Messrs Bickford, Smith, & Co., the original inventors and makers of the safety-fuse, have brought out a new fuse (fig. 25), the action of which will be easily understood from the figure. An ordinary fuse is fixed into a metal case called the igniter, from which a number of instantaneous fuses convey fire to as many separate holes. It is found in practice that this fuse answers very well.

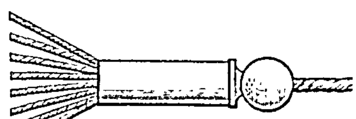


Fig. 25.

Blasting by electricity.

Charges may be readily fired singly or simultaneously with the aid of electricity, either of high tension obtained from a frictional, magneto-electric, or dynamo-electric machine, or of low tension from a galvanic battery. The former is preferred.

Fig. 26 shows a section of one of Brain's high-tension fuses. A is a cylindrical wooden case containing a paper cartridge B,

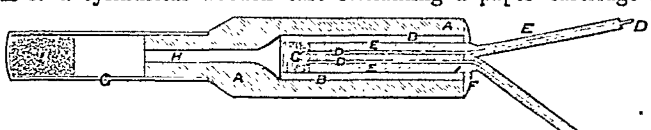


Fig. 26.

with an electric igniting composition C at the bottom. Two copper wires D, D enclosed in gutta-percha E, E reach down to the composition, where they are about $\frac{1}{10}$ inch apart. A copper cap or detonator G is fixed on to the small end of the wooden case. The insulated wires D, D are long enough to reach beyond the bore-hole. The ends of the wires are scraped bare, and one wire of the first hole is twisted together with a wire of the next hole, and so on, and finally the two odd wires of the first and last hole are connected to the two wires of a single cable, or to two separate cables, extending to some place of safety to which the men can retreat. Here the two cable wires are connected by binding screws to a frictional electrical machine or dynamo exploder. A few turns of the handle charge a condenser, and by pressing a knob or by some other device the circuit is completed and the discharge effected. The electricity passes through the fuse wires making a spark at each break, and so firing the electric igniting composition. The flame flashes through the hole H, and ignites the fulminating mercury I, the detonation of which causes the explosion of the dynamite, blasting gelatin, or tonite surrounding the cap.

One great advantage of electric firing is that the miner can retire to a perfectly safe place before attempting to explode the charge. This is important in sinking shafts, where the means of escape are less easy than in levels. A second advantage is that there is no danger of a "hang fire," an occasional source of accidents with the ordinary safety-fuse.

Machine drills.

One of the greatest improvements in the art of mining during the last few years has been the introduction of machinery for boring holes for blasting; most of the machines imitate percussive boring by hand, but a few rotary machines are also in use. A percussive drill or perforator consists of a cylinder with a piston to which the drill is fastened. Compressed air is made to act alternately on each side of the piston, and in this manner the drill receives its reciprocating motion. Various arrangements have been adopted for securing the automatic rotation of the drill. In some cases also the advance forward of the machine, as the hole is deepened, is also effected automatically; but in many of the best drills this work is left to the man in charge. It is impossible within the limits of this article to describe the various drills now in use, or even to make a complete enumeration of them.

The following, in alphabetical order, are the names of some of the best-known drills:—Barrow, Beaumont, Burleigh, Champion, Cornish, Cranston, Darlington, Desideratum, Dœring, Dubois and François, Dynamic, Eclipse, Excelsior, Ferroux, Fröhlich, Ingersoll, Laxey, Mackean, Osterkampf, Rand, Roanhead, Sandycroft, Schram. An account of two of the simplest, the Barrow and the Darlington drills, will be sufficient to give a general idea of the construction of these machines.

Barrow drill.

"The Barrow drill (fig. 27) consists essentially of a gun-metal

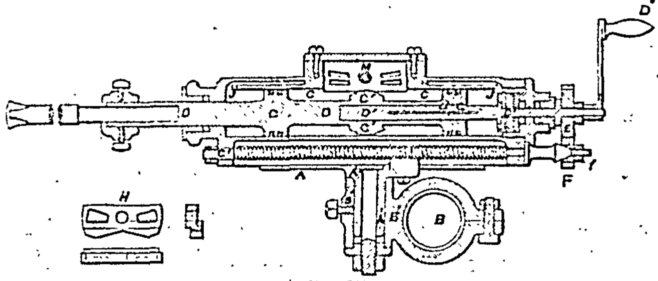


Fig. 27.

cylinder C about 2 feet in length and 4 inches in diameter, in which works a cast-steel piston-rod D, fitted with two pistons G, about 12 inches apart, mid-way between which is the tappet, or boss, G'. In a valve-box on the top of the cylinder is placed the oscillating slide-valve H (shown separately), hinged at M, which is worked by the reciprocation of the tappet G' coming in contact with its lower edges, which for this purpose are formed with two slopes at each end, as shown. It has ports corresponding with openings in the slide-valve face for admitting the fresh steam or compressed air from the inlet pipe I (fig. 28) to the

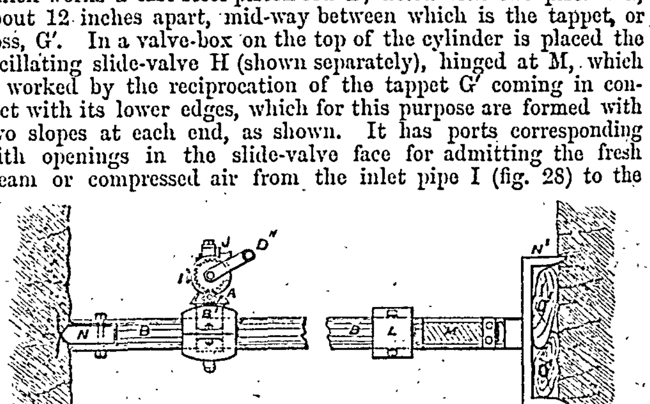


Fig 28.

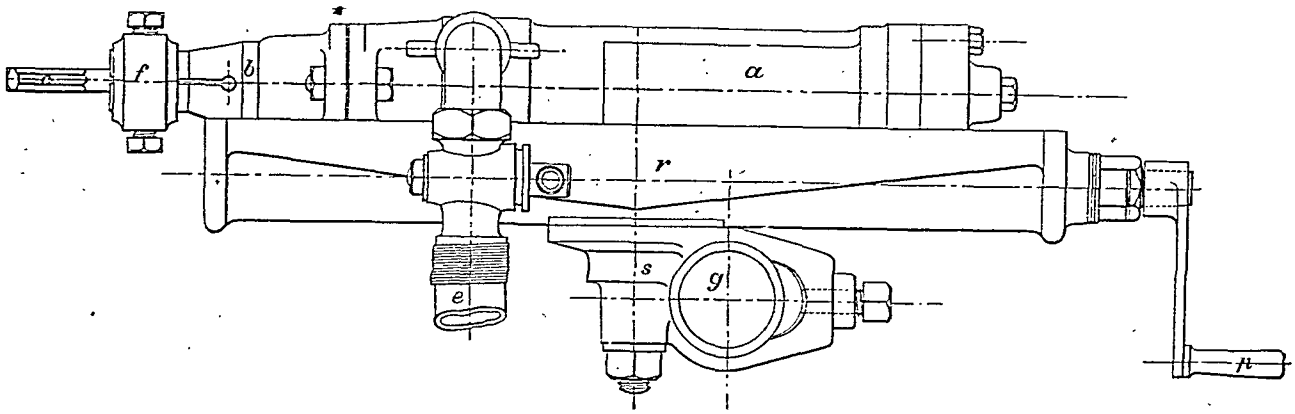
ports j at each end of the cylinder, and for letting the spent or exhaust air or steam escape by the exhaust pipe J. This simple arrangement constitutes the whole valve gear of the machine.

"The borer is inserted into a hole formed in the fore end of the piston rod, and is fixed therein by means of a screw. Its rotation is effected by hand, by means of the handle D'', turning a spindle D', which is so fitted by means of the cotter d, made fast in the piston DG, and fitting in a slot in the spindle D', that the latter can slide in the piston DG, but when turned by the handle causes the piston to turn with it. The spindle D' has a pinion E gearing into the pinion F, on the adjusting and feeding screw C', so that when the piston D is turned by means of the handle D'' the cylinder C is simultaneously pushed along the bed-plate A. These pinions can be easily disconnected by loosening the nut f, and thus the piston and the adjusting screw can be turned independently of one another when required.

"The borers used are respectively $1\frac{1}{4}$ inches, $1\frac{1}{8}$ inches, and 1 inch in diameter, the length of the stroke 4 inches, and the maximum number of blows about three hundred per minute. The air is

brought down about 400 fathoms from surface, at a pressure of 50 to 55 lb to the square inch, in wrought-iron pipes 2 inches in diameter in the shaft, and $1\frac{1}{2}$ inches in the level, and admitted through a flexible tube into the inlet I on the left-hand side of the cylinder. The cost of the pipes is rather under 7d. a foot, or about 3s. 3d. per fathom. The air is compressed at the surface by a 14-inch compressor, worked by a 12-inch horizontal engine, capable, however, of working two machine drills. The gross weight of the machine, including the bed-plate and gudgeon, is about 115 lb."

The method of fixing the machine for work is as follows:—"The bed-plate A of the machine is formed with a gudgeon A′ which fits into, and can be adjusted to any position in, a socket formed in or on a clamp B′, which can be fixed on any part of the wrought-iron bar or column B, thus forming a universal joint. This bar or column



Scale, figs. 29, 30.

Inches 12 9 6 3 0 1 2 Feet.

FIG. 29.—Side Elevation of Darlington's Rock-Drill.—Scale $\frac{14}{100}$.

can be placed in position either horizontally or vertically, as may be most convenient, but is generally placed across the level, against the sides of which it is secured by means of the clamp L, and adjusting screw M, and claws N and N′. If necessary, wooden wedges O, O′ are driven in between the claws and the wall to make it still firmer. The weight of the bar is about 120 lb."[1]

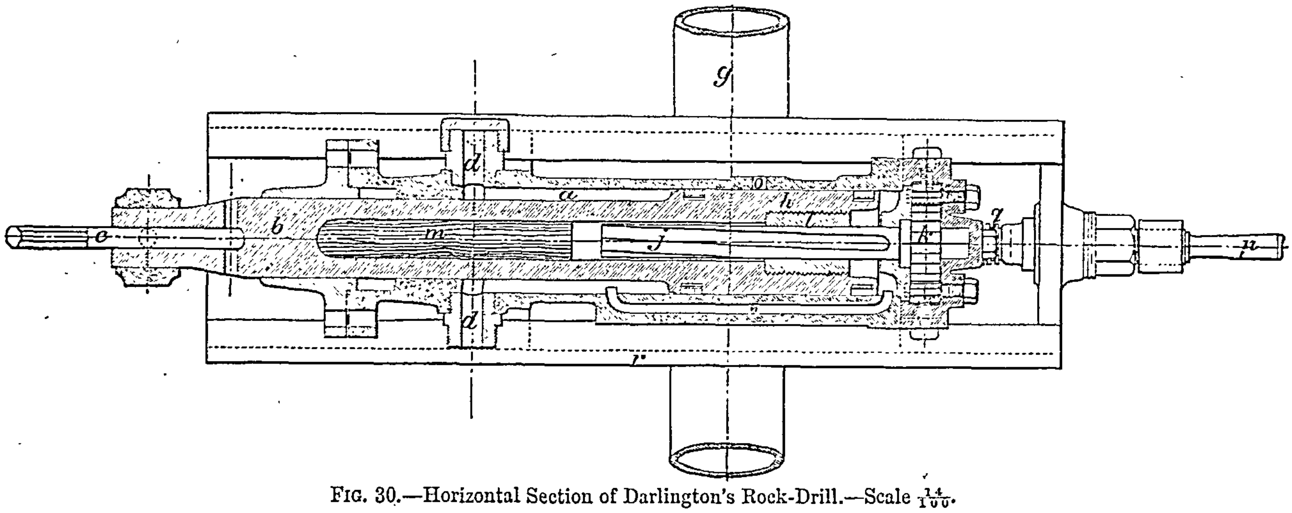


FIG. 30.—Horizontal Section of Darlington's Rock-Drill.—Scale $\frac{14}{100}$.

Air-compressing plant of greater size has now been erected at Dolcoath mine, to which the above description refers. At Snailbeach mine in Shropshire they have two air-compressors of 18 inches

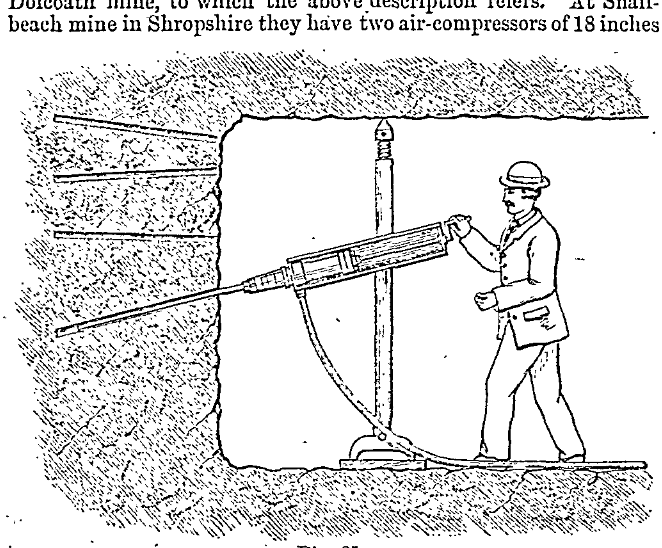


Fig. 31.

diameter and 5 feet stroke; the air-main is at first 9 inches in diameter, then 6 inches, whilst 2-inch gas-pipe is used in the levels.

A rock-drill which has done, and is doing, excellent work is that of Mr John Darlington. Its construction will be understood by referring to figs. 29, 30, and 31; *a* is the cylinder, *b* the piston rod, *c* the borer; *d*, *d* are two openings for bringing in compressed air, either of which may be used according to the position of the drill; *e* is the inlet hose with a stopcock, *f* drill-holder, *g* stretcher bar, *h* piston, *j* rifled bar for turning piston and drill, *k* ratchet wheel attached to rifled bar, *l* rifled nut fixed in the piston head, *m* wood for lessening weight of piston rod and blocking space, *n* portway for allowing the compressed air to pass to the top of the piston and give the blow, *o* exhaust portway. The action of the drill is as follows. The compressed air is always acting on the underside of the piston, and when the upper side of the piston communicates with the outer atmosphere the piston moves rapidly backwards and uncovers the portway *n*. The compressed air rushes through and presses against the upper side of the piston, which has a greater area than the lower side, the difference being equal to the area of the piston rod. The piston is driven rapidly downwards and the drill strikes its blow. At the same time it uncovers the exhaust port *o* and then the constant pressure on the annular area on the underside of the piston produces the return stroke. The number of blows per minute is from six hundred to eight hundred. The rotation of the drill is effected by the rifled bar. On the down-stroke of the piston the bar with its ratchet wheel is free to turn under a couple of pawls, and consequently the piston moves straight whilst the bar and ratchet wheel turn. When the up-stroke is being made the ratchet wheel is held by the pawls and the piston is forced to make part of a revolution. As the hole is deepened the cylinder is advanced forwards by turning the handle *p*; this works an endless screw *q*

Darlington drill.

[1] *Proc. Mining Institute of Cornwall*, vol. i., 1877, p. 12.

passing through a nut attached to the cylinder; *r* is the cradle carrying the feed-screw and supporting the cylinder. It is centred on the clamp *s*. As this clamp can be fixed in any position on the bar, and as the cradle can be turned on the clamp, it is evident that holes can be bored in any direction.

In driving a level with the Darlington drill it is usual to fix the stretcher bar horizontally across the level so as to command the upper part of the face; holes can then be bored with the cradle above the bar or below it. The bar is then shifted low enough to bore the bottom holes. It is found that all the necessary holes can be bored from two positions of the bar. The bar therefore has simply to be fixed twice; the alterations in position for boring holes in various directions are managed by shifting the clamp on the bar and turning the cradle on the clamp. Fig. 31 shows the stretcher bar fixed in a vertical position, which is sometimes convenient.

In order to clear out the sludge from holes that are "looking downwards," a jet of water, supplied from a hose attached to a half-inch gas-pipe leading from a cistern at a higher level, is made to play into the holes during the process of boring.

For sinking shafts Mr Darlington has the drill fixed in a cylindrical case with a large external thread which works in a nut on the clamp. The drill is fed forwards by turning a hand-wheel attached to the case.

Rotating drills.

Rotating machine drills are also used in mines as well as those with percussive action. Stapff pointed out some years ago that, if a rock may be chipped off by power communicated by a blow, it may also be chipped off by a similar amount of power communicated by pressure. Brandt's rotatory boring-machine consists of a hollow borer which has a steel crown with cutting edges screwed on. The tool is kept tight against the rock by the pressure of a column of water, and is at the same time made to rotate by two little water-pressure engines, whilst a stream of water passing down through the borer washes away the débris and keeps the cutting edges cool. In principle, therefore, this drill resembles the original diamond boring machine of De la Roche-Tolay and Perret, save that the crown is made of steel and not of diamonds. During the last few years it has been tried with success in railway tunnels and in mines. Jarolimek's drill[1] acts also by rotation, but the borer is fed forwards and pressed against the rock by a differential screw arrangement. The machine can be worked by hand, or by a little water-pressure or compressed-air engine or an electro-motor. In working certain minerals occurring in seams the undercutting may be performed by machines similar to those used in coal mines (see vol. vi. p. 68).

We now come to the application of the tools and machine drills to the purpose of breaking ground for driving levels and sinking shafts.

Driving levels.

A level or drift is a more or less horizontal passage or tunnel, whilst a shaft is a pit either vertical or inclined. In driving a level by hand labour in hard ground, the first thing the miner has to do is to take out a cut, *i.e.*, blast out a preliminary opening in the "end" or "forebreast." The position of this cut is determined by the joints, which the miner studies carefully so as to obtain the greatest advantage from these natural planes of division. Thus fig. 32 shows a case in which, owing to joints, it was

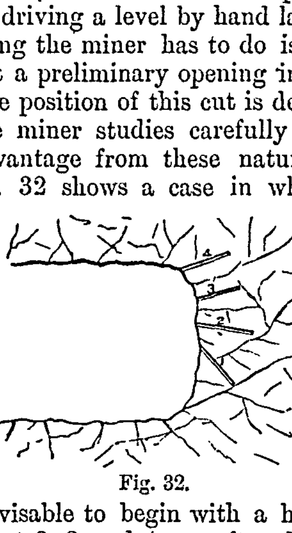


Fig. 32.

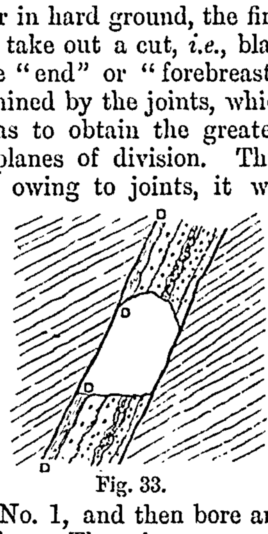


Fig. 33.

advisable to begin with a hole No. 1, and then bore and blast 2, 3, and 4 one after the other. The miner as a rule does not plan the position of any hole until the previous one has done its work; in fact he regulates the position and depth of each hole by the particular circumstances of the case. Though a vein and its walls may be hard, there is occasionally a soft layer of clay (DD, DD, fig. 33) along one wall (*dig*, Cornwall; *gouge*, United States). The miner then works this away with the pick, and, having excavated a groove as deep as possible, he can now blast down the lode by side holes and so push the level forward.

Sinking shafts.

In sinking a shaft a similar method of proceeding is observed. A little pit (*sink*) is blasted out in the most convenient part, and the excavation is widened to the full size by a succession of blasts, each hole being planned according to circumstances. This series of operations is repeated, and the shaft is thus gradually deepened.

Where boring machinery is employed, less attention, and sometimes no attention, is paid to natural joints, because when once the drill is in its place it is very little trouble to bore a few more holes, and the work can then be carried on according to a system which is certain of effecting the desired result.

Driving levels with machine drills.

A common method of procedure for hard ground is shown in figs. 34 and 35. Four centre holes are bored about a foot apart at first, but converging till at a depth of 3 feet they are within 6 inches, or less, of each other. Other holes are then bored around them until the end is pierced by twenty or thirty holes in all. The four centre holes are then charged and fired simultaneously, either by electricity or by Bickford's instantaneous fuse, and the result is the removal of a large core of rock. The holes round the opening are then charged and fired, generally in volleys of several holes at a time, and the level is thus carried forward for a distance of 3 feet. If the ground is more favourable fewer holes are required, and they may be bored deeper,—in fact as much as 6 feet in some instances. Occasionally the four centre holes are directed so that they meet at the apex of an acute pyramid, and then, after all have been charged with blasting gelatin, only one of them receives a primer and cap; the shock of the explosion of one charge fires the other three adjacent charges simultaneously. The preliminary opening is not necessarily made in the centre of a level, and sometimes it is blasted out in the bottom or one side.

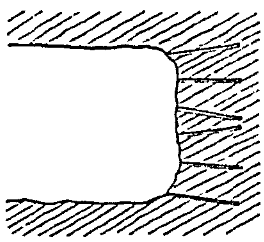


Fig. 34.

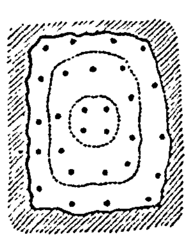


Fig. 35.

Sinking shafts with machine drills

In sinking shafts by boring machinery operations are conducted much in the same way as in levels, save of course that the holes are directed downwards. Figs. 36 and 37 are a section and plan of a shaft which is now being sunk at the Foxdale mines in the Isle of Man. About forty-five holes are bored in the bottom of the shaft before the drills are removed; two of the holes A, B, and occasionally four, are bored only 4 feet deep, and are blasted with ordinary fuse. They serve simply to smash up and weaken the core; then the six holes nearest the centre, which are 8 feet deep, are blasted all together with Bickford's instantaneous fuse, and the result is the removal of a large core leaving a deep *sink*. The remaining holes are fired in volleys of four at a time in the ordinary way. In this manner the shaft, which is in hard granite, is being deepened at the rate of 3½ or 4 fathoms a month. Tonite is the explosive used.

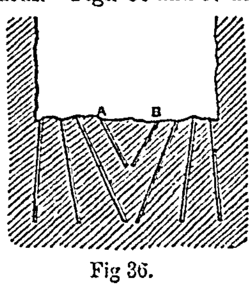


Fig 36.

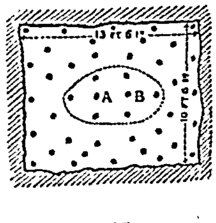


Fig. 37.

Sundry machines have been invented and used for driving levels without blasting. Some cut up the face into small chips which can

[1] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1881.

easily be removed, but they have not made their way at present into ordinary mining. The Bosseyeuse of MM. Dubois and François acts on a different principle. It is a strong machine worked by compressed air. It first of all drills holes 4 inches in diameter by percussion; a striking head is then substituted for the drill, and wedges, on the principle of the plug and feathers, are inserted into the holes; and powerful blows with the striking head wedge off the rock in lumps. This machine is being used with success in Belgium for driving levels and crosscuts in fiery mines.

Some comparative experiments between hand-labour, a percussive drill, and a rotatory drill have lately been made in one of the Freiberg mines,[1] and the results are of much interest and importance. The actual figures are as follows, the cost including, in the case of the machines, interest, depreciation, and cost of repairs, and cost of steam-power, supposing water-power not available:—

	Hand-boring.	Schram's Drill.	Brandt's Drill.
Distance driven per week (in metres)	0·95	4·5	5·0
Cost in marks per metre driven	120 to 123·5	77·4 to 85·25	74·34
Wages realized by the miners, in marks, per 8 hours shift	1·85 to 2·05	3·48 to 3·66	3·76

The advantages of machine work are very marked indeed both as regards rate and cost of driving, and wages earned by the men. Brandt's rotatory drill did its work cheaper and faster than Schram's machine; but nothing is said in the original notice of the advantage of a machine driven by compressed air for ventilating workings such as advanced headings in which these drills are employed.

Brandt's machine was worked with water at a pressure of 83½ atmospheres, of which 56·6 atmospheres were obtained by pressure pumps provided with an accumulator, and 26·9 atmospheres by natural fall, owing to the working level being 277 metres below the pumps. The water was conveyed to the machine in iron pipes of 1½ inches diameter inside. The diameter of the holes bored was 2¾ inches, and they could be bored in gneiss at the rate of 1½ inches per minute. The stretcher bar on which the machine is carried is hollow, and has a piston which can be forced out by hydraulic pressure so as to fix the bar firmly. A similar bar is sometimes used with percussive drills.[2]

As a method of breaking ground the ancient process of fire-setting requires to be mentioned. Before blasting was known it was largely employed, but its use is now confined to a few places on the Continent where the rocks are exceedingly hard and where wood is abundant and cheap. Piles of wood are heaped up against the face of the workings and set on fire. On returning to the working place two or three days afterwards, when the rocks have cooled a little, it is found that the ground has split and flaked off, and that much has been loosened which can be removed by the pick and wedge.

We finally come to water as an agent for removing rocks. Streams of water were formerly used in South Wales for working beds of clay ironstone at the outcrop. The water washed away the clay and shale and left the clean nodules of ironstone. The china clay of Cornwall is also worked by water: a stream of water is turned on to the soft mass, and the workman loosens the ground with a pick; the water carries off the particles of decomposed rock in suspension to regular settling pits. Water under pressure has rendered vast services to the miner in working auriferous alluvia. The system is described and figured at p. 746 of vol. x., so it is unnecessary here to enter into details. In the special case of salt-mines recourse may be had to the solvent action of water, directed by suitable jets, for making excavations.

Modes of paying miners.

5. *Principles of Employment of Mining Labour.*—As a large proportion of the expenditure in mining is for actual manual labour, it is very important that means should be taken to prevent any waste in this department. Three principles are in vogue—payment by time, by work done either measured or weighed, and by the value of the ore extracted.

The overseers, called captains in many metal mines, are naturally paid by the month, and where strict supervision can be exercised, such as is possible at the surface, on the dressing-floors for instance, the same principle may be adopted; but when men are working underground, and often in small gangs of only two or three persons at some distance apart, piecework of some kind is more economical and satisfactory in every way.

In driving levels and sinking shafts it is usual for the men to work at a certain price per running yard or fathom. The agents have to see that the excavation, whether shaft or level, is maintained of the full dimensions agreed upon, and preserved in the proper direction. At the end of a certain time, generally a month, the work is measured by the agent. From the gross amount obtained by multiplying the price by the number of fathoms driven or sunk it is necessary to deduct the cost of the materials supplied to the men by the mining company, such as explosives, steel, candles, &c., and the remainder is divided among the persons who took the contract. When the useful mineral is being obtained the men may be paid at so much per cubic yard or fathom excavated, or at so much per ton of mineral extracted; the overseer of course has to see, in this latter case, that worthless rock is not sent to the surface. Payment by the number of inches bored is a method in use in some countries, where the men are not experienced or enterprising enough to undertake the work in any other way. A foreman points out to the men the position and direction in which the holes must be bored, measures them when completed, and subsequently charges and fires them.

The third method is that which is known as the tribute system. The miner working on tribute is allowed to speculate upon the value of the ore in a certain working area assigned to him and called his *pitch*. He gives the mining company all the ore he extracts at a certain proportion of its value, after he has paid all the cost of breaking it, hoisting it to the surface, and dressing it. Thus, supposing he takes a pitch at 5s. in the £, and produces marketable copper ore of the value of £50, his share will be 50 × 5s. = £12, 10s., less the cost of the materials he has been supplied with, and all expenses for winding, dressing, sampling, &c.

6. *Means of Securing Excavations by Timber, Iron, and Masonry.*—The following kinds of timber are those most frequently employed for securing excavations underground: oak, larch, pitch pine, spruce fir, and acacia. In many mines the timber is attacked by dry rot, which gradually renders it useless, and when the timber has often to be renewed the expense may be very considerable. Various methods of preventing dry rot have been tried with more or less success, such as letting water trickle over the timber in the mine or treating it with preservative solutions beforehand. Brine, creosote, and solutions of chloride of zinc, sulphate of zinc, sulphate of copper, and sulphate of iron increase the duration of timber. It was found by experiments carried on at Commentry during a long series of years that one of the best plans was to soak the timber for twenty-four hours in a strong solution of sulphate of iron. The total cost was only ½d. per yard of prop, whilst the timber lasted eleven times as long as when this simple treatment was omitted. Timbering.

Timber is used in various forms—either whole and merely sawn into lengths, or squared up, or sawn in half, or sawn into planks of various thicknesses.

Where the roof of a bed is weak it may be kept up by simple props; but in some coal-mines and clay-mines a better support is obtained by logs (*chocks*) laid two by two crosswise (fig. 38).

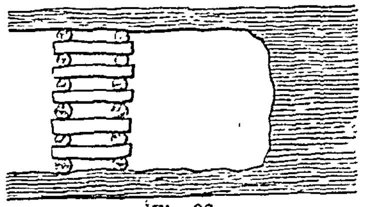


Fig. 38.

Though a level is an excavation of a very simple nature, the methods of timbering it vary considerably, because the parts requiring support may either be the roof alone, or the roof and one or two sides, or the roof, sides, and bottom.

If the roof only is weak, as is the case with a soft lode between two hard walls, a *cap* with a few boards resting on it (fig. 39) is sufficient to prevent falls. If one side is weak the cap must be

[1] *Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen auf das Jahr* 1882, p. 18, and abstract in *Proc. Inst. Civ. Eng.*, vol. lxix., 1881–82, part iii. p. 51.

[2] *Annales des Mines*, ser. 8, ii., pl. 1, fig. 6, 1882.

supported by a side prop or *leg* (fig. 40), and very often by two legs. The forms of joint between the cap and leg are numerous

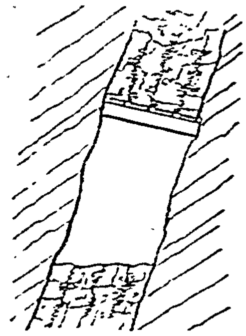


Fig. 39.

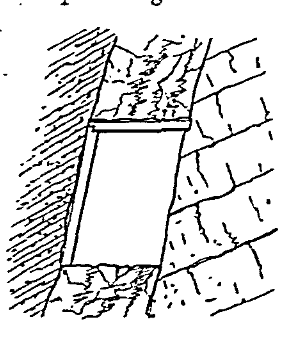


Fig. 40.

(fig. 41), depending to a great extent upon the nature of the pressure, whether coming upon the top or sides. With round timber the top of the leg is sometimes hollowed as shown in fig. 42 A, but occasionally the joint is flat and a thick nail, or *nog*, is put in (fig. 42 B) to prevent the effects of side pressure, or, better, a piece of thick plank is nailed under the cap (fig. 43). Where the floor of a level is soft and weak, a sole-piece or *sill* becomes necessary, and, if the sides or roof are likely to fall in, a lining of poles or planks is used (fig. 43).

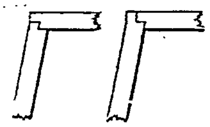


Fig. 41.

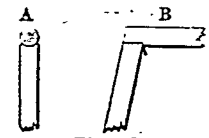


Fig. 42.

In some very heavy ground in the Comstock lode a special system of timbering is adopted (fig. 44).

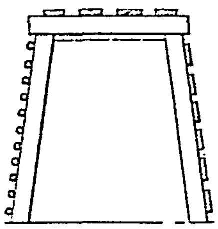


Fig. 43.

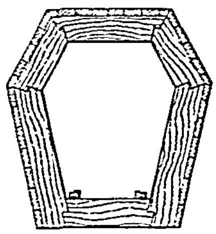


Fig. 44.

If the ground is loose, so that the roof or sides, or both, will run in unless immediately supported, the method of working called *spilling* or *poling* is pursued. It consists in supporting the weak parts by boards or poles kept in advance of the last frame set up. The poles or boards (*laths*) are driven forward by blows from a sledge, and the ground is then worked away with the pick; as soon as a sufficient advance has been made a new frame is set up to support the ends of the poles or boards and the process is repeated (figs. 45 and 46). In running ground it is necessary to have the laths fitting closely together, and the working face also must be supported by *breast-boards* kept in place by little struts resting against the frame. These are removed and advanced one by one after the laths in the roof and side have been driven beyond them.

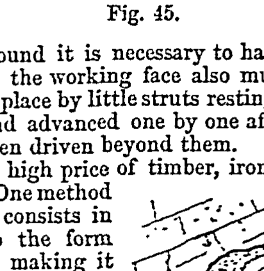


Fig. 45.

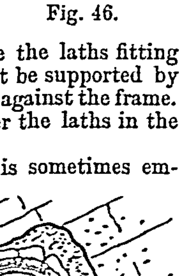


Fig. 46.

Iron supports. On account of the high price of timber, iron is sometimes employed in its place. One method in use in the Harz consists in bending a rail into the form shown in fig. 47 and making it support other rails laid longitudinally, against which flattish stones are placed; the vacant spaces are then filled with rubbish.

Masonry. Masonry has long been used for supporting the sides of mining excavations. The materials necessary are stone, ordinary bricks, or slag-bricks, and they may be built up alone (*dry walling*) or with the aid of mortar or hydraulic cement. The bottom of a level is occasionally lined with concrete to carry a large stream of water, which otherwise might run into lower workings through cracks and crevices. Dry walling is not uncommon, and it may be combined with the use of timber (or iron) as shown in fig. 69, in which a level is maintained between two walls keeping back a mass of rubbish.

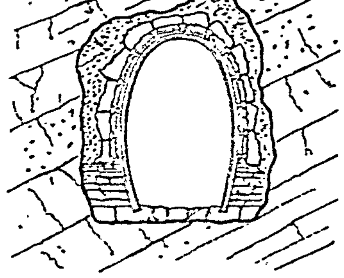


Fig. 47.

Figs. 48 and 49 show methods of securing a drift by arches when a lode has been removed.

Timbering for shafts. The timbering required for shafts varies according to the nature of the ground and the size of the excavation. A mere lining of planks set on their edges (fig. 50) suffices for small shafts, corner pieces being nailed to keep the successive frames together. In some of the salt-mines of Cheshire the shafts are lined with 4-inch planks united by mortice and tenon joints.

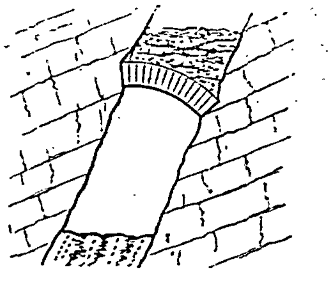


Fig. 48.

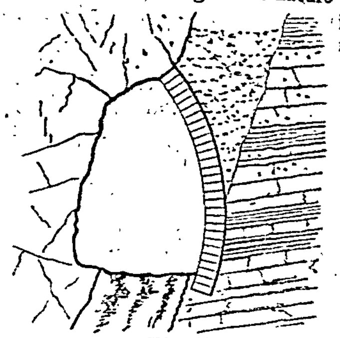


Fig. 49.

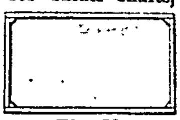


Fig. 50.

The usual method of securing shafts is by *sets* or *frames*. Each set consists of four pieces, two longer ones called *wall-plates* and two shorter ones called *end-pieces*. They are joined by simply halving the timber as shown in fig. 51. A more complicated joint (fig. 52) is often preferred. The separate frames are kept apart by corner pieces (*studdles*, Cornwall; *jogs*, Flintshire), and loose ground is prevented from falling in by boards or poles outside the frames.

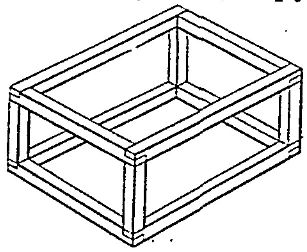


Fig. 51.

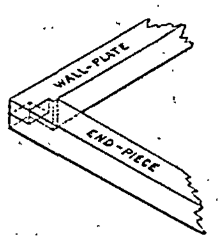


Fig. 52.

As shafts are frequently used for the several purposes of pumping, hoisting, and affording means of ingress and egress by ladders, it becomes necessary in such cases to divide them into compartments. Pieces of timber parallel to the end-pieces (*buntons* or *dividings*) are fixed across the shaft, and serve to stay the wall-plates and carry the guides as well as to support planks (*casing boards*) which are nailed to them so as to form a continuous partition or brattice. The magnificent timbering of some of the shafts on the Comstock lode is described by Mr James D. Hague as follows:[1]—"The timbering consists of framed sets or cribs of square timber, placed horizontally, 4 feet apart, and separated by uprights or posts introduced between them. Cross-timbers for the partitions between the compartments form a part of every set. The whole is covered on the outside by a lagging of 3-inch plank placed vertically." Figs. 53, 54, and 55, copied from Mr Hague's plates, illustrate this method

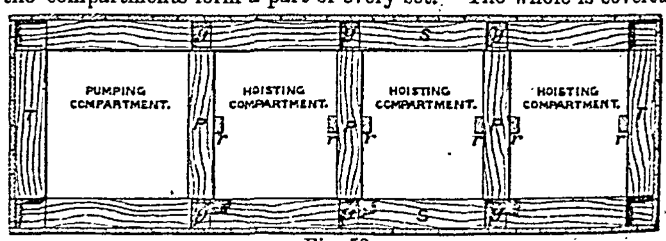


Fig. 53.

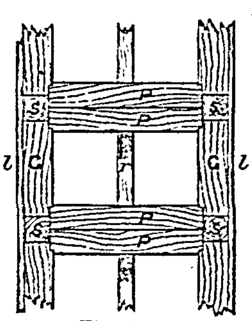


Fig. 54.

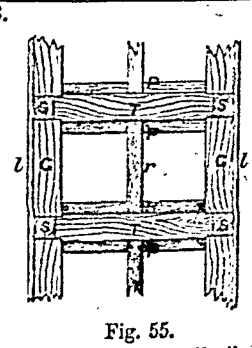


Fig. 55.

[1] *United States Geological Exploration of the Fortieth Parallel*, vol. iii., "Mining Industry," p. 103.

of timbering: Fig. 53 is a plan of the shaft: "S, S are the longitudinal or sill-timbers, T, T the transverse end-timbers, P partition-timbers, r guide-rods between which the cage moves, g gains cut in the sill-timbers, to receive the ends of the posts. The sheathing or lagging is seen enclosing the whole frame." Fig. 54 is a transverse section through the partition P of fig. 53, "between the pumping compartment and the adjoining hoisting compartment, looking towards the latter. In this figure, G, G are the posts, S the sill-timbers, P the partition-timbers, the ends of which are framed with short tenons that are received in gains cut in the sill-timbers and the ends of the posts, r guide-rod, l lagging or sheathing." Fig. 55 is an end view of the frame shown in fig. 53. "The single piece T forms the end, while the double pieces P forming the partitions are seen beyond." "The outer timbers of each set, that is, the two sides and ends of the main frame, are 14 inches square; the posts, ten in number, four at the corners and two at each end of the three partitions, are of the same size. The dividing timbers, forming the partitions, are 12 inches square."

When ground is loose or running, recourse must be had to a *spilling* process like that described for levels. Strong balks of timber are fixed at the surface or in solid ground, and then the first frame is hung from these *bearers*, and each successive frame from the one above it. Iron bars with cotters may be used for suspending the sets; but on the Comstock lode each bolt is made in two parts with a tightening screw in the middle, and the sets can thus be kept very firmly together. The laths are driven in advance, in the manner explained in the case of levels, and a new frame is put in as soon as the excavation has been sufficiently deepened within the protecting sheath of boards. In very unstable ground it may be necessary to put in the frames touching each other, so that the shaft becomes encased in a solid box of timber, occasionally 14 inches thick.

Masonry for shafts.

Like levels, shafts may be lined with masonry or brickwork, and these have the advantage of being far more permanent than timber, and of requiring fewer repairs. This kind of shaft-lining is especially desirable in the loose ground near the surface; because, if the working is discontinued temporarily, the shaft still remains secure and available for use at any future time, whereas if timber is put in it often decays, the top of the shaft collapses, and much expense is incurred in the process of reopening it. The section of the shafts that are walled is generally circular as affording the best resistance to pressure; but elliptical walling is also met with. Another shape is like a rectangle, save that the sides, instead of being straight, form curves of large radius. The walling may be dry or with mortar, according to circumstances.

The masonry is put in either in one length or in successive portions in descending order, and this is the usual plan. The shaft is sunk a certain depth, with temporary timbering if necessary, and when firm ground has been reached a bed is cut out round the shaft, and on this is placed a crib or curb AB (fig. 56)[1] consisting of segments of timber which form a ring. This serves for a foundation for the brickwork, which is built up to the surface; the temporary timbering is removed, and the space filled up with earth or concrete. Sinking is then resumed below the curb, and for a certain distance of a smaller diameter, so as to leave a bracket, or ledge, to support the first curb. On arriving, after a certain depth of sinking, at another firm bed, a second curb CD is put in and a portion of brickwork built up. When the ledge of rock is reached, it is carefully removed in small sections and the brickwork brought up to the first curb. This process is repeated till the shaft is completed, or reaches rock in which no masonry is requisite. If, owing to the nature of the ground, it is impossible at first to find a firm seat for the curbs, it becomes necessary to hang them by iron bolts from a strong bearing frame at the surface.

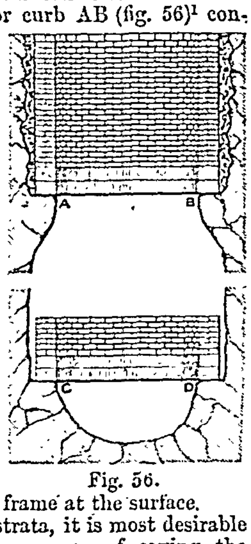


Fig. 56.

When shafts pass through very watery strata, it is most desirable to stop all influx into the mine for the purpose of saving the heavy expense of pumping. The manner in which this is effected by a watertight lining, known as tubbing, is described in the article COAL, vol. vi. p. 62, where will also be found an account of Triger's plan of sinking shafts with compressed air, and the very successful method of boring shafts through water-bearing ground invented by Messrs Kind & Chaudron.

Exploitation.

7. *Exploitation, or Working Away of Veins, Beds, and Masses.*—We have described how shafts are sunk and levels driven, and we now come to the processes employed in removing the mineral.

[1] J. Callon, *Lectures on Mining*, vol. i., Atlas, plate xxviii.

The deposit must first of all be reached by a shaft, or, where the contour of the country permits it, by a level. In the case of a vein an exploratory shaft is often sunk on the course of the lode for 20 or 30 fathoms, and, if the indications found in a level driven out from this shaft warrant further prosecution of the mine, a first working shaft is sunk to intersect the lode at a depth of 100 fathoms or more from the surface. Crosscuts are then driven out at intervals of 10, 15, or 20 fathoms to reach the lode, as shown in fig. 57, which represents a section at right angles to the line of strike. Sometimes the main shafts are carried down all the way along the dip of the deposit, though perpendicular shafts have the advantages of quicker and cheaper winding and cheaper pumping, to say nothing of the possibility of utilizing the cages for the rapid descent and ascent of the miners. If an inclined shaft appears to be advisable, great care should be taken to sink it in a straight line. In either case levels are driven out along the strike of the lode as shown in the longitudinal section fig. 58, in the hopes of meeting with valuable ore-bodies such as are represented by the stippled portions of the figure. For the purpose of affording ventilation, and still further exploring the ground and working it, intermediate shafts, called *winzes* (Cornwall) or *sumps* (North Wales), are sunk in the lode.

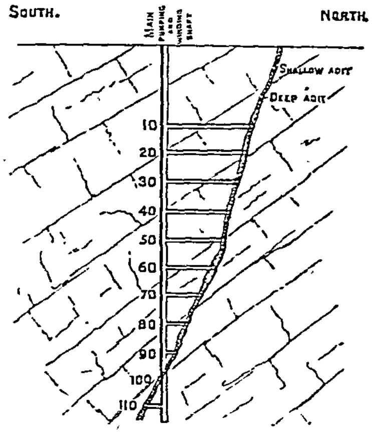


Fig. 57.

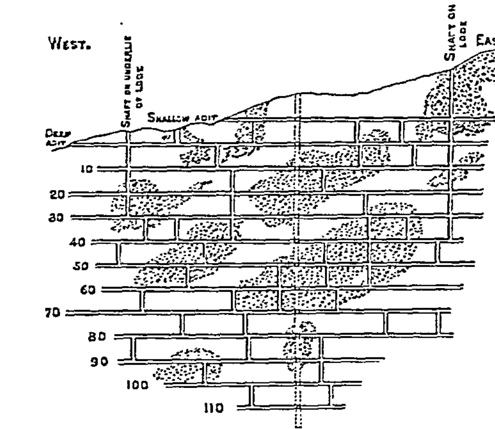
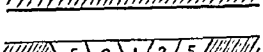


Fig. 58.

The actual mode of removing the lode itself depends a good deal upon circumstances, viz., its width, the nature of its contents, and the walls that enclose it; but the methods of working may generally be brought under one of two heads, viz., underhand stoping or overhand stoping. The word *stope* is equivalent to step, and the term stoping means working away any deposit in a series of steps. *Underhand* or *bottom stopes* are workings arranged like the steps of a staircase seen from above, whilst *overhand* or *back stopes* are like similar steps seen from underneath. Both methods have their advantages and disadvantages, and both are largely used.



Underhand stoping.

We will first take underhand stoping, as this is the older method. In the old days the miner began in the floor of the level (fig. 59), and sank down a few feet, removing the part 1; he followed with 2, 3, 4, &c., until the excavation finally presented the appearance shown in fig. 60. Any valueless rock or mineral was deposited upon platforms of timber (*stulls*), and the ore was drawn up into the level

Fig. 59.

by a windlass. One great disadvantage of this method is that the ore and water have to be drawn up some distance by hand labour; much timber is required for the stulls if there is a large quantity of worthless stuff in the vein, or if the sides are weak. The advantages are that ore can be worked away as soon as the level is driven, that the men are always boring downwards, and, lastly, that the ore can be carefully picked after it is broken, without fear of any valuable particles being lost.

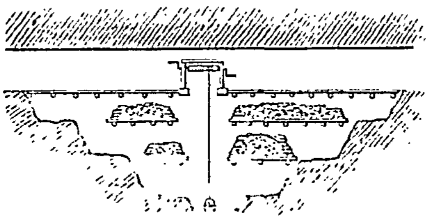


Fig. 60.

A more economical method of working by underhand stopes, and one largely employed in Cornwall at the present day, consists in reserving any attack upon the ore-ground until a lower level has been driven. An intermediate shaft (*winze*) between the two levels is then made, either by sinking from the upper level or rising from the lower one. The work of stoping is commenced at the two upper ends of the winze, and the lode is removed in a succession of steps, the workings assuming the appearance exhibited in fig. 61. The steps are generally made steep, so that the ore may readily roll into the winze, and so that the bore-holes may do better execution; but these steep stopes are dangerous if a man happens to slip and fall. The huge open chasms left by the removal of a large lode in this way are also a source of danger; for there is always a risk of falls of rock, and from places which cannot easily be examined.

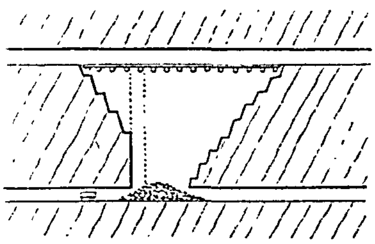


Fig. 61.

Figs. 62 and 63, kindly supplied by Captain Josiah Thomas,[1] explain the general arrangement of the workings of the largest tin mine in Cornwall. The lode after producing copper ores to a considerable depth changed its character and became rich in tin. The workings for tin ore are confined almost entirely to the granite. The section fig. 62 shows that the main shaft of the mine is at first vertical and then carried down on the dip of the lode.

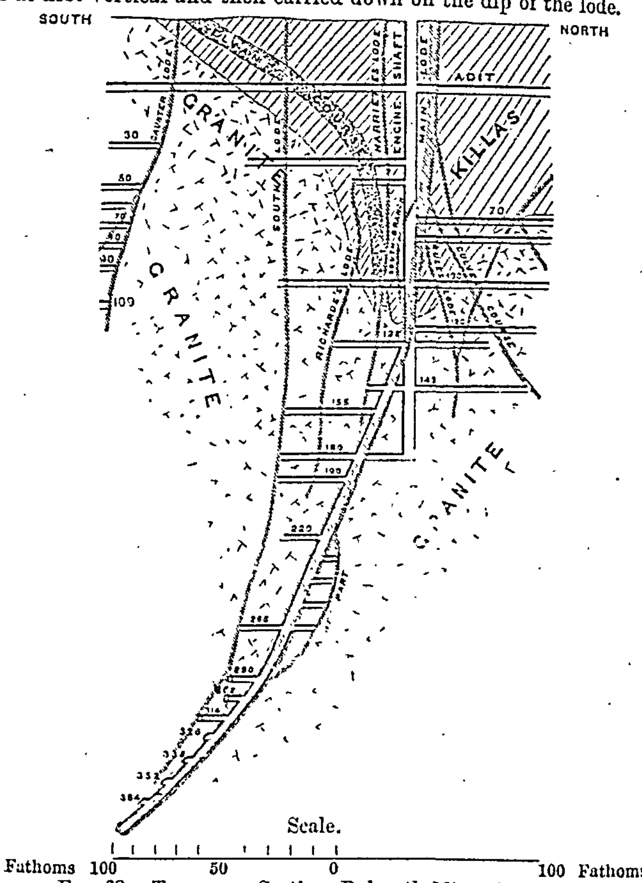


FIG. 62.—Transverse Section, Dolcoath Mine, Cornwall.

The process of overhand stoping is precisely the reverse of that

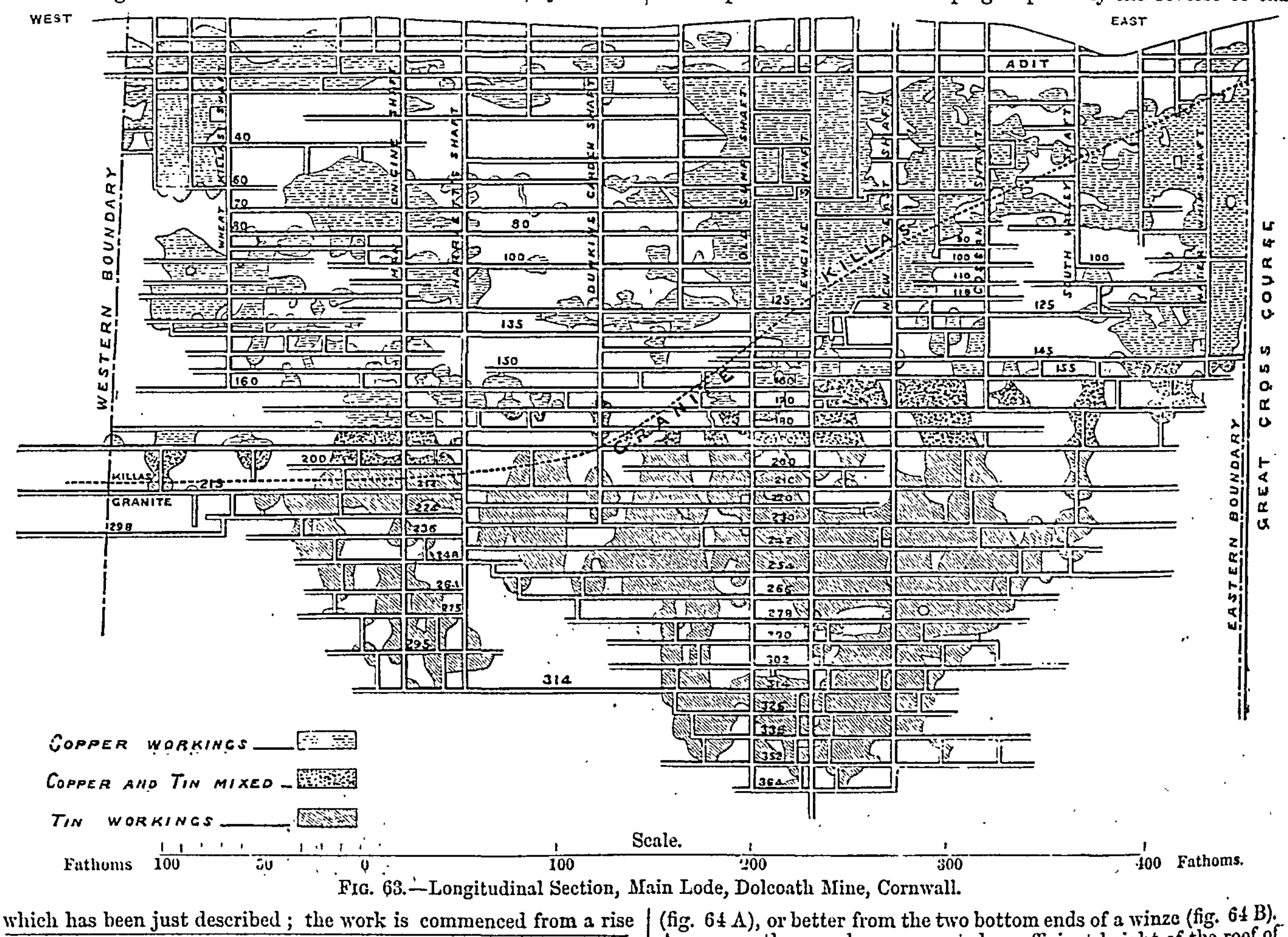


FIG. 63.—Longitudinal Section, Main Lode, Dolcoath Mine, Cornwall.

which has been just described; the work is commenced from a rise (fig. 64 A), or better from the two bottom ends of a winze (fig. 64 B). As soon as the men have excavated a sufficient height of the roof of the level, they put in strong pieces of timber from wall to wall, and

[1] See *Report of Miners' Association of Devon and Cornwall for* 1882, and R. J. Frecheville, *Trans. Roy. Geol. Soc. Cornwall*, vol. x. part v.

cover these cross-pieces (*stempels, stull-pieces*) with boards or poles, and throw down the rubbish upon the platform (*stull, bunning*) thus formed. In the midst of the rubbish chimney-like openings (*mills, passes*) are reserved, lined with boards or dry-walling, and

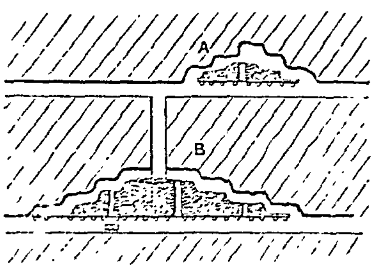


Fig. 64.

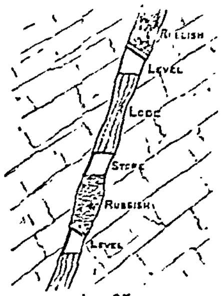


Fig. 65.

closed at the bottom with shoots provided with doors. The ore is thrown into these passes, which are tapped when necessary; the ore falls into the tram-waggon placed ready to receive it.

Fig. 65 gives a transverse section showing the rubbish resting on the stull. This is what may be called the typical method of stoping, when the lode affords rubbish enough for the men to stand on and to keep them close to the rock they are attacking. Very often such is not the case, and the whole of the lode has to be sent to the surface for treatment. If the walls are firm, the lode is sometimes stoped away, a stull put in, and a sufficient heap of broken ore is left upon the stull to give the men good standing ground; the excess is thrown over the ends of the stull, or the great heap is tapped by cutting a hole in the stull-covering, and allowing a quantity to run down into the level.

Another method consists in putting in temporary stages upon which the men stand to do their work, whilst the excavation is left as an open space (fig. 66).

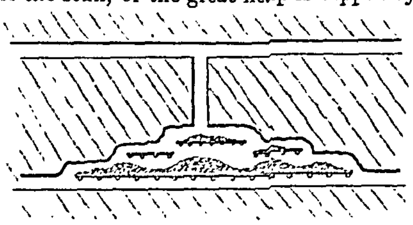


Fig. 66.

This mode of working is incompatible with weak walls. If a lode does not afford rubbish enough for completely filling up the excavated space, or if it is too narrow for men to do their work comfortably, one of the walls may be cut into and blasted down (fig. 67), so that the men always stand upon a firm bed of rubbish while at work, and there is no fear of a collapse of the mine. In certain special cases rubbish is sent down from the surface to fill up the excavations.

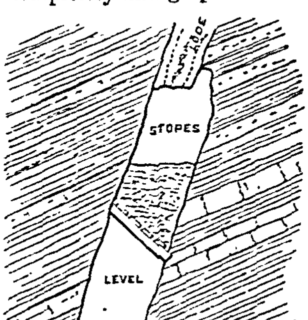


Fig. 67.

The advantages of overhand stoping are—that the miner is assisted by gravity in his work, that no ore or rock has to be drawn up by hand labour, and that less timber is required. On the other hand, the miner is always menaced by falls, but as he is close by he can constantly test the solidity of the roof and sides by sounding them with his sledge; there is the further disadvantage that particles of ore may be lost in the rubbish, but this loss is often prevented by laying down boards or sheets of iron while the lode is being broken down.

Working wide lodes.

When very wide lodes come to be worked, recourse is often had to special methods. The great lode at the famous Van mine, in Montgomeryshire, is sometimes 40 feet in width, and the hanging wall is weak. The lode is stoped away overhand, and the cavities packed with rubbish, part of which is derived from the lode itself, whilst the greater portion is supplied from a special quarry at the surface. Fig. 68[1] explains the details of the case. A is the original cross-

Van mine.

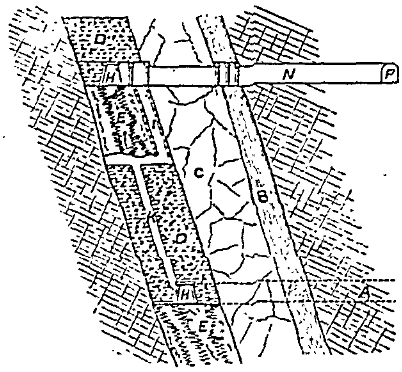


Fig. 68.

cut (not in the line of section) by which the lode was reached, B is the *flucan*, C the bastard lode, generally worthless, E the main lode, H permanent levels, and K *ore-pass* reserved amidst the rubbish (*deads*) D, I *pass* down which rubbish is shot, N crosscut connecting the level H with P the permanent level in the *country*.

If the lode is not firm enough to allow of the stopes being carried for its full width, the crosscut method is adopted; the workings in this case, instead of proceeding along the strike, are carried across the deposit from one wall to another.

The lode is removed in successive horizontal slices A, B, C, D, E, and for each slice a level (L, fig. 69) is driven, either in the lode,

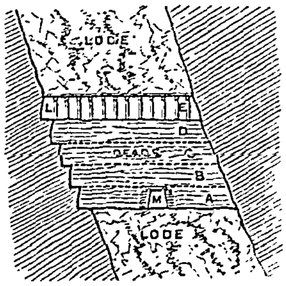


Fig 69.

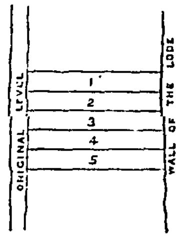


Fig. 70.

or partly or entirely in the country; from this level crosscuts are put out 6 or 8 feet wide, as shown in the plan (fig. 70). These are regularly timbered according to the necessities of the case, and, when No. 1 is completed, No. 2 is begun, and the rubbish from No. 2 thrown into the empty space of No. 1 crosscut. If the quantity is insufficient, deads are brought in from the surface or from exploratory workings in worthless rock in the neighbourhood. Sometimes the crosscuts are not driven side by side, but 1 and 5 would be driven first, leaving 2, 3, and 4 as a solid pillar; then 3 would be worked away, and finally 2 and 4 between the timber and rubbish on each side. The greater part of the timber can be recovered when the next slice above is taken off, as the props are put in with the small ends downwards, and can be drawn up with levers. M (fig. 69) is a level reserved in the deads for traffic and ventilation. This method of working is applicable not only to lodes but also to irregular masses.

In working away the soft "bonanzas" or ore-bodies of the great Comstock lode, which are from 10 to 30 or even 40 or 50 feet wide, and which are enclosed in very unstable ground, a special method of timbering is employed (figs. 71 and 72).[2] "It consists in framing timbers together in rectangular sets, each set being composed of a square base placed horizontally, formed of four timbers, sills, and cross-pieces, 4 to 6 feet long, framed together, surmounted by four posts 6 to 7 feet high, at each corner, and capped by a frame-work, similar to that of the base. These cap-pieces, forming the top of any set, are at the same time the sills or base of the next set above, the posts, as the sets rise one above the other in the stope, being generally placed in position directly over those below." "The timbers are usually of 12-inch stuff square-hewn or sawn." Each post has a tenon 9 inches long at the upper end, and a tenon of 2 inches at the lower end, which fit into mortices in the cap and sill respectively; and "the sills and caps have short tenons on each end and shoulders cut to receive the ends of the post and the horizontal cross-pieces." The walls of the excavation are sustained by a lagging of 3-inch or 4-inch plank. The whole width of the ore-body is stoped away at once, and its place supplied by timbering, and finally the vacant space is filled with waste rock derived from dead work in the mine or from special excavations,—underground quarries in fact,—in barren ground. The stoping is carried on overhand, starting from an intermediate shaft or winze, and fig. 73 will explain how the different frames are built up one above the other.

Comstock lode.

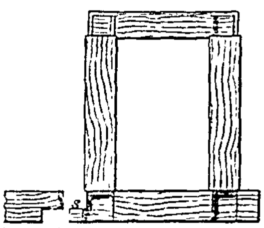


Fig. 71.

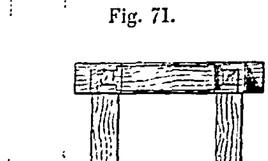


Fig. 72.

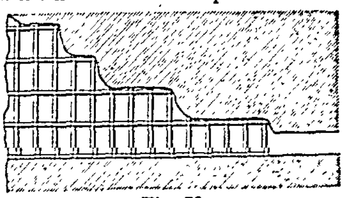


Fig. 73.

Another method of working a wide lode is to attack it in slices

[1] C. Le Neve Foster, "Notes on the Van Mine," *Trans. Roy. Geol. Soc. Cornwall*, vol. x. p. 41.

[2] James D. Hague, *United States Geological Exploration of the Fortieth Parallel*, vol. iii. "Mining Industry," p. 112.

parallel to the dip, working away each slice separately as if it were a lode of ordinary dimensions, and filling up with rubbish (fig. 74).

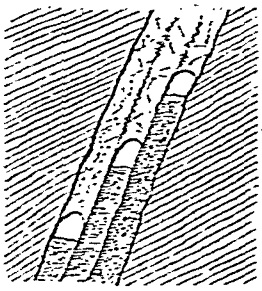


Fig. 74.

Working of beds. We now come to beds or seams. The mode of working the most important beds that occur in the earth's crust, viz., coal seams, has already been described in the article COAL (vol. vi. p. 64 *sq.*), and details have been given concerning the removal of the mineral by pillar working and long-wall working. Both these methods are applicable in the case of seams of other minerals. Such for instance are the beds of fire-clay and clay-ironstone which are wrought by both the processes just mentioned, and often in connexion with coal.

Next in importance to coal is ironstone, and a brief account of the workings in the Cleveland district will explain the manner in which more than one-third of the iron ore raised in the British Isles is obtained by mining. It resembles the "bord and pillar" system used for working coal in Durham.

Cleveland ironstone workings. The Cleveland ore occurs in the form of a bed from 6 to 16 feet thick in the Middle Lias, lying pretty level. A mainway (*fig. 75*) is driven about 12 feet wide for a considerable distance, and at right angles to it *bords* are driven 5 yards wide for a length of 30 yards, and then at right angles a *wall* 7 or 8 feet wide and 20 yards long. By drivages of this kind the bed is cut up into pillars or blocks 30 yards long by 20 yards wide. The pillars are subsequently removed in the following way. A *place*, or drift, *ab*, 6 feet wide, is driven across the pillar 10 yards from the corner, and portions (*lifts*) about 6 yards wide are worked away in the order 1, 2, 3. After No. 1 lift has been removed, the timber put in to support the roof temporarily is withdrawn, and the roof is allowed to fall; No. 2 is then taken, and No. 3 in the same way. While these lifts are being taken out, another place *cd* is being driven across the pillar 10 yards from the first, and the pillar removed entirely by a series of fresh lifts.

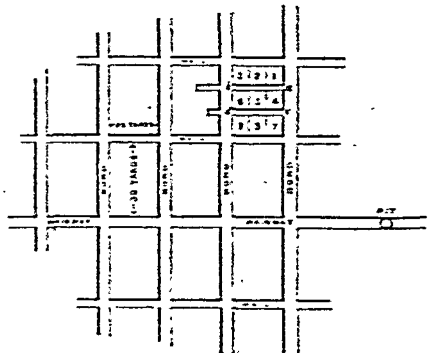


Fig. 75.

Gypsum quarries. Fig. 76 represents in section and plan the chambers and pillars of the underground gypsum quarries which supply the well-known plaster of Paris to all the world.[1] The principal bed is from 50 to 60 feet in thickness; pillars are left 10 feet square at the base, and the *stalls* between them are 16 feet wide. The workings are slightly arched, and are not carried up to the roof, for the purpose of better maintaining the security of the chambers, because heavy damages would have to be paid if they "caved in" and rendered the surface useless. A similar layer left for the floor prevents *creep* (see COAL, vol. vi. p. 64), and enables the underground roads to be kept in good repair.

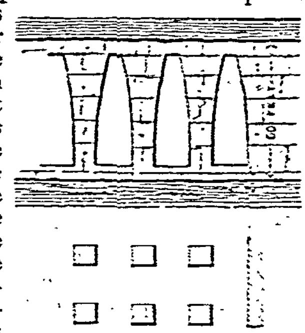


Fig. 76.

Slate quarries. Underground slate quarries afford examples of very various methods of removing thick beds of mineral of comparatively little intrinsic value. At Angers in France, where the beds dip at a high angle, the underground workings are carried on like an open quarry

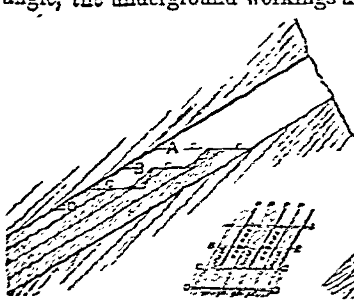


Fig. 77. Fig. 78.

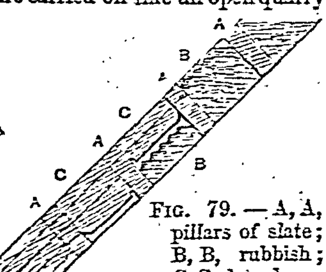


Fig. 79.—A, A, pillars of slate; B, B, rubbish; C, C, slate chambers. Scale $\frac{1}{2000}$.

under a strong roof of slate; the floor is continually being worked away in steps, and an immense open chamber is left. In the Festiniog district in North Wales the principal bed, or *vein* as it is called, is more than 100 feet thick in places, and the method of working consists in making alternate pillars and chambers each 30 feet to 50 feet wide along the strike (cross-section and plan, figs. 77 and 78). The pillars follow lines of natural cross-rending PP', which commonly make an angle of 25° to 35° with the direction of the dip. The excavations are arranged in regular lines, and form continuous chambers extending very often from the surface to the very lowest workings. A, B, C, D are the original working levels. The slate of the supporting pillars is entirely lost, as these cannot be removed with safety. This method of working requires a strong roof. In the Ardennes, on the contrary, the pillars are carried along indefinitely along the strike (fig. 79, cross-section). The slate in each longitudinal chamber is removed in slices parallel to the bedding, and the men stand upon the rubbish, which finally fills up the chambers completely.

Rock-salt constitutes another important mineral which occurs in the form of stratified deposits. The principal source of the Cheshire salt is a bed 84 feet thick lying horizontally; but only the bottom part, 15 feet to 18 feet thick, is mined. Pillars 10 yards square are left promiscuously about 25 yards apart, as shown in fig. 80, which represents part of Marston Hall rock-salt mine.[2] The workings Salt mines.

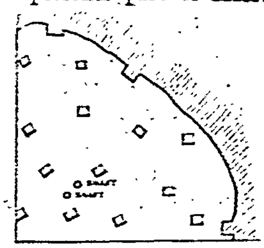


Fig. 80.

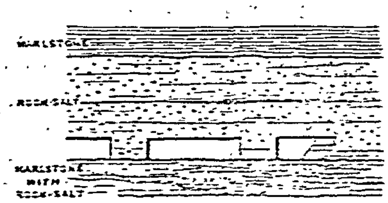


Fig. 81.

are advanced by making in the upper part an excavation 5 feet 9 inches high, called the *roofing* (*a*, fig. 81); and then the lower two-thirds of the part worked are removed by blasting slanting holes. Many of the old salt mines have collapsed from weakness of the roof or insufficiency of the pillars, and have become inundated; the brine is then extracted by pumping and evaporated for salt.

In some countries, especially when the beds of salt are impure or much mixed with clay or shale, the formation of brine is conducted regularly by making a network of drivages within a rectangular, elliptical, or circular area in thick beds of saliferous marl, and then introducing fresh water by pipes, so as to form underground ponds which gradually dissolve the roof and sides. The brine is drawn off and either pumped up or conveyed by adits to the surface.

A few words remain to be said about open workings. Some minerals are always obtained in this way; others are worked open before regular underground mining begins; and, thirdly, it often happens that underground and surface work are both carried on simultaneously on the same deposit. Among deposits worked opencast are peat, numerous kinds of stone, iron ore, cupreous pyrites, lead ore, gold- and tin-bearing alluvia, and diamantiferous rock. Open workings.

Owing to its soft, spongy, and fibrous texture, and the fact of its often lying below the water-level, peat has to be worked in a special manner. Trenches are dug about a foot deep with a sharp spade, which cuts out sods of convenient size for drying and burning. When one layer has been removed in this way, another is taken off, and so on. If water is reached the working can still be pursued by using the long spade (*grand louchet*, France) with a handle of 16 or 20 feet. It cuts out a sod 3 or 4 feet long at each thrust.

When a deposit is more or less solid the workings are frequently arranged in steps, the height and breadth of each depending upon the firmness of the rock.

In many cases the first work consists in removing worthless rock at the surface (*overburden*), and where the underlying deposit is thick or very valuable it will pay to remove a very great thickness of overburden, on account of the advantages of working a deposit open. These advantages are—entire removal of the deposit without loss in pillars, no expense for timbering or for packing with rubbish or for ventilating or lighting the workings, better ventilation, easier supervision, longer working hours, less danger.

As an example of a large open working may be mentioned the great Penrhyn slate quarry near Bangor, employing about 3000 hands, and worked by a succession of terraces on an average 60 feet high by 30 feet wide (fig. 82). Reference has already been made to the thick lead-bearing sandstone of Mechernich, which is in part worked as an open quarry. Mokta-el-Hadid, near Bona in Algeria, and the Rio Tinto mines in Spain, afford instances of extensive combined open and underground workings for iron ore and cupriferous pyrites respectively.

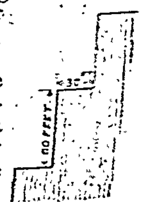


Fig. 82.

Local laws regulating the size of the working areas, or claims,

[1] Callon, *Lectures on Mining*, vol. ii. plate xli.

[2] Joseph Dickinson, "Report on the Salt Districts," *Reports of the Inspectors of Mines for the year* 1881, p. 63.

Diamond mines. owned by separate individuals or companies, considerably affect the methods of working. This is especially the case with the diamond deposits of South Africa. The diamantiferous rock at the celebrated Kimberley mine (formerly called Colesberg Kopje) occurs in the shape of an elliptical upright mass, the greatest length being about 330 yards and the greatest breadth about 200 yards. The superficial area is about 9 acres; the mass extends downwards within almost perpendicular walls of shale, and is worked in places to a depth of about 400 feet. The claims are only 31 feet square, and are more than four hundred in number, and these have in some instances been subdivided into portions as small as the sixteenth of a claim; but, as at the present time one company may own very many claims, the number of individual holdings is less numerous than formerly when the limit was two claims. The working is carried on vertically downwards, and, as the claims are not all worked at the same rate, those that progress most rapidly are surrounded by perpendicular walls of neighbouring claims. The shale, or *reef*, enclosing the deposit is constantly falling into the huge open pit, and has to be cut away to a slope, the expense of this work being charged to the claim-holders generally by the mining board. The diamantiferous rock is extracted by innumerable wire-rope inclines.

Evils attending hydraulic mining. We have already referred to the method of working gold-bearing alluvia by the hydraulic process, which has rendered such services in the United States (GOLD, vol. x. p. 746). At the same time one must not be blind to the evils of this method of working, which have at last necessitated legislative interference. Some idea of the extent of the mischievous results of hydraulic mining will be gathered from the statement that one working alone, the Gold Run Ditch and Mining Company, for the last eight years has been discharging 4000 to 5000 cubic yards of sand, gravel, and boulders daily, for a period of five months each year, into a tributary of the Sacramento. As a natural consequence deposits are formed lower down the river, obstructing the navigable channels, rendering overflows more frequent and destructive, and causing valuable land to be destroyed by deposits of sand. The superior court of Sacramento county, California, has recently decided that the hydraulic mining companies must build dams to impound the coarse and heavy débris, or take other efficacious means to prevent their being washed down the rivers.

Underground transport. 8. *Carriage or Transport of Minerals along the Underground Roads.*—After the mineral has been broken down in a deposit it is necessary to pick out any barren rock and then convey to the surface all that is of value.

Carriage by workers. The simplest and oldest method of transport along underground roads is carriage on the back, and this method may still be seen at the present day even in countries where the art of mining is generally highly advanced. Thus, for instance, in the little slate mines near Cochem on the Moselle men and lads carry up all the blocks of slate upon their backs, walking upon steps cut in the rock; they come up with their hands upon the ground bent almost double under the weight of the block, which rests upon a thick pad. Again, the blocks of slate are still carried on the back from the actual working place to the nearest tram-road, in the slate mines of the Ardennes. In the Sicilian sulphur mines the same method is common, and it is found also in parts of Spain and China, where baskets are used, whilst bags are employed in Mexico and also in Japan. Even in England the system still survives in the Forest of Dean, where boys carry iron ore in wooden trays from the very irregular ore-producing cavities either to the surface or to the nearest shaft.

Sledges. Sledges, or *sleds*, enable greater loads to be transported; but they are not available unless the conveyance is along roads sloping downwards. They have been largely employed in coal mines, and are still resorted to in some collieries for conveying the coal from the working place to the nearest tram-road.

Wheel carriages. We next come to wheeled carriages. The simplest is the wheelbarrow. The barrow used in Cornwall at the present day is not unlike that figured more than three centuries ago by Agricola. The navvy's barrow is more advantageous, but it requires a wider and higher level. The barrow runs upon the natural floor of the level, upon boards, or upon thin strips of iron. Carts drawn by horses may be used in large underground quarries. Excepting in special cases it is advisable to replace barrows by waggons running upon rails. The oldest form is the German *Hund.* It consists of a rectangular wooden body, with four wheels, resting upon two boards as rails, and it is kept on the track by a pin which runs between the boards.

Cast-iron tram-plates were introduced in the last century, and were finally succeeded by iron rails, which are now in general use, though steel threatens to displace iron in this as in other departments of mining. Various forms of rail are employed. The simplest is a bar of iron set on its edge in transverse sleepers, or flat iron nailed to longitudinal sleepers. Small T-headed and bridge rails are not uncommon. In the Harz the rails sometimes lie on stone sleepers; a hole is bored in the stone, plugged with wood, and the rail is nailed on. The gauge varies from 14 inches to 3 feet or more; 20 inches to 22 inches is a common gauge in metal mines. Arrangements of course have to be made for passing from one line to another by *points*; but the transference is frequently best effected by putting down flat plates of cast iron, upon the smooth surface of which the waggons can be handled with ease and turned in any direction; raised ledges guide the wheels into any particular track.

The form and size of the waggons running upon the rails necessarily vary according to the size of the underground roads and the manner in which the mineral is raised in the shaft. In some mines the practice exists of loading the mineral in the level into an iron bucket (*kibble*) standing upon a *trolley*, which is merely a small platform upon wheels. This trolley is pushed (*trammed*) to the shaft; the full kibble is hooked on to the winding-rope and drawn up, whilst an empty kibble is placed upon the trolley and trammed back along the level, where it is again loaded from a shoot (*mill, pass*) or by the shovel. The usual plan, however, is to have a waggon, which is tipped on coming to an enlargement of the shaft (*plat, lodge*) where the level joins it. These waggons may be made of wood or sheet-iron, and of late years sheet-steel for the body and cast-steel for the wheels have been coming into favour.

The most modern system in metal mines is to imitate collieries, and use waggons which are drawn up in cages. Fig. 83 represents the plain but strong waggon of the Van mines, consisting of a rectangular body of sheet-iron resting on an oak frame, and provided with cast-steel wheels. The wheels are loose upon the axles, which themselves run loose in the pedestals. The waggon is emptied by being run on to a "tippler," which enables it to be completely overturned with great ease. A commoner plan is to construct the waggon with a hinged door at one end, and the contents are discharged by opening this door and raising the body.

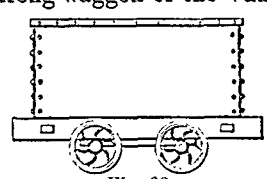


Fig. 83.

The motive power for tramming waggons along the levels of metal mines is generally supplied by men or boys, though, where large quantities have to be extracted, and where the roads are favourable, recourse may be had to ponies and horses and the various kinds of mechanical haulage described in COAL, vol. vi. p. 69.

Trains of cars are sometimes drawn along underground railways by locomotives; they have the great disadvantage of polluting the air with the products of combustion, and consequently they are not available unless the ventilation is very good. A small locomotive of 2 horse-power nominal is used on an 18½-inch track in the adit-level of the Great Laxey mine (Isle of Man), now approaching a mile in length, and full-sized locomotives ply along the adit of the Rio Tinto mines. Locomotives worked by compressed air improve the ventilation instead of injuring it, and are not a source of danger in cases where fire-damp may be present; but, except in special cases, they cannot be worked so cheaply as engines fired with coal. Conveyance by electric railroads underground has hardly gone beyond the experimental stage, but the results obtained at the Zaukeroda colliery in Saxony[1] show that electricity can be applied with profit in this department of mining.

A few instances of transport by boats may still be met with. Boats. The boats used in the underground canal at Klausthal are 31 feet

[1] *Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen auf das Jahr* 1883, p. 50.

long by 4 feet 6 inches wide, and 2 feet 11 inches deep. Each boat carries 5 or 6 tons.

Where roads have a strong gradient, inclined planes are employed, either self-acting if the mineral has to be lowered, or worked by stationary engines if the mineral has to be raised (see COAL, vol. vi. p. 69).

Winding. 9. *Winding, or Raising in the Shafts, with the Machinery and Apparatus required.*—In speaking of the transport by underground roads, we mentioned that the mineral is occasionally brought to the surface on the backs of men or boys. In other cases daylight is reached by adit-levels provided with railroads; but in by far the greater number of mines it is necessary to hoist the mineral, and often much rubbish, up vertical or inclined pits generally known as shafts.

In beginning to sink a shaft from the surface, or in sinking a winze, hand-power applied by a windlass is sufficient. The broken rock at the bottom of the shaft is shovelled into a wooden or iron bucket (*kibble*), which is drawn up by a rope passing round the barrel of the windlass. When a depth of 20 or 30 yards has been reached it is more advantageous to introduce horse-power, and the usual machine by which this power is applied, called a *gin* or *horse-whim*, is a common sight in many metalliferous districts. It consists of a vertical axis carrying a barrel or drum 8 to 12 feet in diameter, round which is coiled the rope, which after passing over a pulley hangs down the shaft. The axis carries an iron pin at each end, the lower one working in a stone and the upper one in a socket in the span-beam or cross-bar of the supporting frame. Under the barrel is a long driving beam to which a horse is harnessed, and, as will be readily understood, the kibble is drawn up or lowered down as the horse walks round. It is most economical to have two kibbles, for then they balance each other.

Where steam and water-power are not available, a large number of horses or mules are sometimes harnessed to whims, and ore raised from depths of 200 fathoms. These, however, are exceptional cases; and, especially since the introduction of portable engines, the use of steam-power even for comparatively small depths, such as 100 yards, is daily increasing. In hilly districts water-power is generally at hand, and huge reservoirs are frequently constructed for storing the rainfall, and so affording an adequate and constant supply. It may be utilized by water-wheels, turbines, and water-pressure engines.

There are three systems of winding by steam or water-power which are in regular use:—(1) by buckets (*kibbles*), baskets, or bags swinging loose in the shafts; (2) by boxes working between guides (*skips*, Cornwall); (3) by cages carrying one or more waggons.

Buckets. The buckets are made of wood, sheet-iron, or sheet-steel. Their shape varies; it may be round or elliptical, straight in the side or bulging in the middle. Fig. 84 represents a kibble made of sheet-iron. When the shaft is inclined, the side upon which the kibble slides is carefully lined with boards (*bed-planks*) resting upon cross sleepers. Planks of hard wood like beech last longer and require fewer repairs than deal boards. In the Harz, poles fixed lengthwise take the place of boards, which are customary in Great Britain. Even where shafts are perpendicular a lining of planks is often put in round the winding compartment, unless the space is considerable, and the kibble then glides up smoothly, and there is less risk of accidents. A more modern system is to use wire-rope guides for the kibble, which is thus kept from swinging about. Another advantage of this plan is that a light cage can easily be substituted for the kibble and used for the ascent and descent of the men. Mr Galloway has patented a method of sinking shafts with wire-rope guides, the upper ends of which are coiled upon drums at the surface. By adopting this expedient the guides can be lengthened as the shaft is deepened.

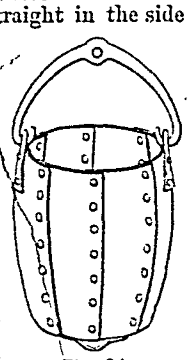


Fig. 84.

A word must be said about the actual loading and emptying of the kibble. Sometimes, as already mentioned, the kibble is filled at the working place or from a shoot (*pass*, Cornwall) carried down into the level, and then conveyed on a trolley to the shaft, where it is hooked on to the rope and drawn up. More frequently the filler standing in the *plat* loads the kibble with a shovel; and in order to save time two kibbles are often provided, one being filled while the other is making the journey to and from the surface. In this case it is necessary to have some kind of *clevis*, which will enable the kibble to be readily detached from the winding-rope, and quickly and securely fastened on again. On its arriving at the surface the *lander* seizes an eye or ring at the bottom of the kibble by a pair of tongs suspended by a chain, and the rope is now lowered. The kibble is thus turned over and the contents fall into a tram-waggon.

The inconveniences of this method of winding are considerable, especially in inclined shafts where the direction and amount of the inclination are not constant. There is great wear and tear of the bed-plank and casing-boards; and, unless constant attention is paid to repairs, places are worn out where the kibble catches, causing the rope to break. The fall of a kibble and its contents not only does much damage to the shaft, but also is a source of danger to the men. The introduction of boxes (*skips*) working between guides or conductors was therefore a decided step in advance, for the system allows the winding to be carried on with less friction and with greater rapidity and safety. The guides are often made of pieces of timber (like *r*, fig. 53) bolted to the end-pieces and dividings. It is only in perpendicular shafts that guides made of wire-rope or iron rods can be applied. The skip is a box of rectangular section made of sheet-iron or sheet-steel, with a sloping bottom, and provided with a hinged door closed by a bolt for discharging its contents. Fig. 85 [1] shows how the skip runs upon Skips.

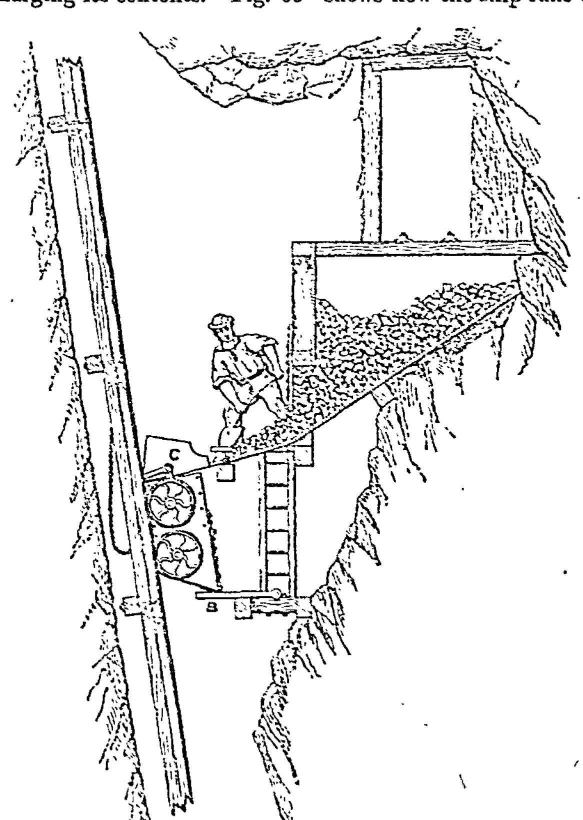


Fig. 85.

the guides by means of four cast-iron or (better) cast-steel wheels. In an inclined shaft the guides sometimes have iron rails laid on them so as to diminish the wear. Some of the skips in Cornwall are made to hold as much as a ton and a half of tin-bearing rock. The skip is filled with a shovel by a man standing in the plat, but a better plan is to arrange shoots leading from large hoppers, so that the ore can be made to run in without any shovelling. The skip is sometimes tilted completely over instead of being emptied by a hinged door; this arrangement is in use in some of the German mines, where the skip is made of wood, and is guided on each side by two pins or rollers running between two conductors. When the skip has reached the surface two catches are made to support the lower rollers, whilst the upper ones pass through openings in the front guides, and the skip, turning upon the lower ones, is tipped over and so emptied.

The most satisfactory system of winding is by cages; there is Cage. less handling of the mineral, and the hoisting proceeds at far greater speed. This system, which is almost universal in collieries, is employed also for working deposits of other minerals, and, though

[1] Moissenet, *Annales des Mines*, ser. 6, vol. ii., 1862, plate vii.

in vein-mining the skip and kibble still prevail in England, the managers are beginning to recognize the advantages of the cage and equip their mines with more modern appliances than have hitherto been customary. The cages used in the mines on the Comstock lode are very light and simple in construction, as will be seen from fig. 86. The cage in fact is a mere timber platform, 5 feet by 4,

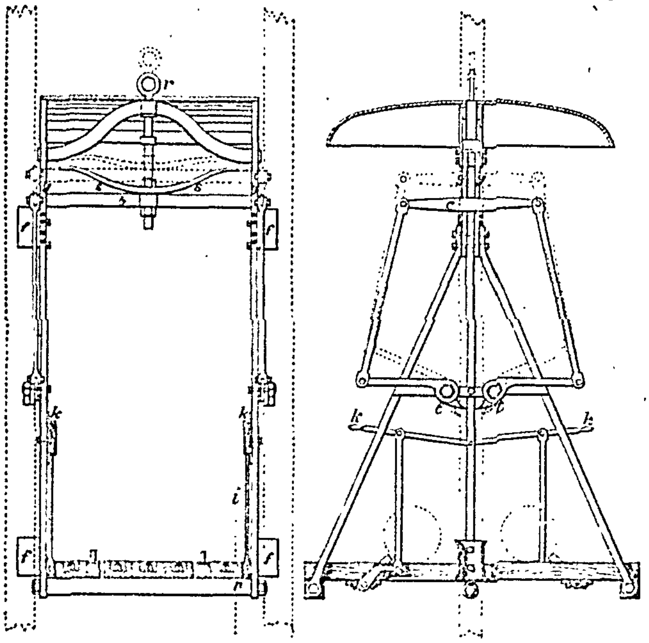


FIG. 86.—Cage used in Comstock Lode.

resting on iron bars p, and supported by iron rods on each side. It is provided with a sheet-iron bonnet to protect the men if they are inside, and also with safety catches t, t, which come into play if the rope breaks. The hand levers k, k at the ends of the cage raise up blocks which keep the car in its place during the ascent or descent; g, g are guides for the end of the crossbar b; c, bar working teeth t, t by levers; f, "ear" or "shoe" embracing the guide-rod in shaft; r, lifting bar; s, strong spring.

The most important details concerning the use of cages, ropes, and other hoisting appliances such as pulleys, pulley-frames, detaching hooks, and winding engines, have already been set forth in the article COAL, vol. vi. p. 74; and it is therefore needless to repeat these particulars, especially as the art of winding mineral cheaply, speedily, and safely has been carried to a far greater pitch of perfection in collieries than in the majority of metal mines. It is often convenient to fix winding engines underground for the purpose of sinking shafts and winzes, and drive them by compressed air brought down in pipes from the surface.

Koepe system. The Koepe system of winding, which appears to be viewed with favour on the Continent, consists in having what is practically an endless rope with one large sheave over the shaft, in the place of the two drums. There are two cages, and the rope below them acts as a counterbalance, so that the load is uniform throughout.

Blanchet's method. The most novel hoisting apparatus is that of M. Blanchet (COAL, vol. vi. p. 76), which has now been regularly at work in the Hottinguer shaft at Épinac in France for the last six years. M. Blanchet's method consists in fixing in the shaft a large pipe in which is arranged a piston; from this is suspended a cage carrying waggons. By exhausting the air above the piston the load is gradually forced up by the atmospheric pressure below it. The Hottinguer shaft is 660 yards deep, and the pipe is 5 feet 3 inches in diameter, made up of a succession of cylinders of sheet-iron about $\frac{5}{16}$ inch thick and 4 feet 4 inches high, joined by flanges and bolts. The 485 rings composing the long pipe weigh altogether 418 statute tons. The cage has nine decks, and arrangements are made for unloading three at a time; each waggon holds half a ton, so that the total useful load is $4\frac{1}{2}$ tons. The speed of hoisting is 20 feet per second. If two hoisting pipes are connected the dead weights may be made to balance each other, and the power required is simply that which is necessary to overcome the weight of the useful load. All the men prefer the pneumatic hoist to the ordinary cage for descending and ascending the mine, and are regularly lowered and raised by it. The advantages claimed by M. Blanchet for this system are—(1) the possibility of hoisting from depths at which rope-winding would no longer be practicable; (2) getting rid of the costly ropes and dangers connected with rope-winding; (3) better utilization of the engine power; (4) improvement of the ventilation and diminution of the amount of fire-damp.

10. *Drainage.*—The mineral having been raised to the surface, the task of the miner might appear to be at an end; but this is not the case, for it is further necessary that he should keep his mine free from water and foul air. These two indispensable operations of draining and ventilating frequently require special appliances which add considerably to the general cost of mining.

In all cases where it is possible, endeavours should be made to keep the water out of a mine, so as to save the expense of pumping it; and the method of putting in a watertight lining (*tubbing*) in a shaft has been already described (COAL, vol. vi. p. 62). When large streams of water happen to be intersected by underground workings, and threaten to overpower the available pumping machinery, or when it is advisable to save the expense of draining abandoned workings, the entry of this water into the mine may often be prevented by stoppings, called *dams*, constructed of timber or brickwork. Drainage.

In spite of all precautions, the miner generally has to contend with water which percolates into the workings. Four methods of getting rid of this water are available, viz., adits, siphons, winding machinery, and pumps.

An adit, day-level, or sough is a nearly horizontal tunnel with one end opening at the surface, allowing the water to drain away naturally. In hilly countries mines are often worked entirely by adits, and even when a mine is deepened below the drainage level the utility of the adit is still threefold:—it lessens the quantity of water which tends to percolate into the lower workings; it lessens the depths to which the water has to be pumped; and, by furnishing a certain amount of fall, it enables water to be applied as power. On account of these important advantages some very long and costly adits have been driven for the purpose of aiding the miners in certain metalliferous districts. Adits.

Thus in the Harz the Ernest Augustus adit ("Ernst August Stolln") has been driven a distance of nearly $6\frac{1}{2}$ miles into the Klausthal district. The total length of the adit, including the branches, is no less than 14 miles. It intersects many of the lodes at a depth of upwards of 400 yards from the surface. The total cost of this adit is estimated at £85,500.

Another long adit is the celebrated "Rothschönberger Stolln," which unwaters some of the most important mines at Freiberg in Saxony. The length of the main or trunk adit is more than $8\frac{1}{2}$ miles; the gradient of the greater part of it is only 1·18 inch in 100 yards. The branches of this adit among the mines are more than 16 miles in length, so that the total length of the main adit with its branches amounts to nearly 25 miles. Many of the mines are now drained naturally to a depth of 250 to 300 yards. The cost of the main tunnel was £359,334, or nearly £24 per yard, but this includes the cost of eight shafts, heavy expenses for pumping from these shafts, the walling of the adit for $\frac{3}{4}$ mile, and all general expenses. The length of time occupied in driving this adit was thirty-three years. The "Kaiser Josef II. Erbstolln" in Hungary is another remarkable mining tunnel, which was commenced in 1782, and completed in 1878 at a total cost of 4,599,000 florins. It is $10\frac{1}{4}$ miles in length, extending from the valley of the river Gran to the town of Schemnitz, where it intersects the lodes at depths varying from 300 to 600 yards according to the contour of the surface.

In Cornwall the Great County adit was driven for the purpose of relieving the Gwennap mines of their water, and it was pushed on nearly to Redruth. This adit differs from the great works undertaken in Germany by the fact that it commences in the mining district, and, though the length of all the drivages amounts to more than 30 miles, the water from the most distant mine does not run more than about 6 miles before reaching daylight. The average depth is only 70 or 80 yards from the surface. In fact this great adit, though a work of great utility when the Gwennap district was in a flourishing condition, is merely a network of comparatively shallow drivages, often along the lodes themselves, among the mines, and therefore for boldness of execution cannot for one moment be compared to the great Schemnitz, Freiberg, and Klausthal drainage tunnels which have just been mentioned. The Blackett Level in Northumberland is an adit which has been driven a distance of about $4\frac{3}{4}$ miles, and it will have to be extended about 2 miles further before reaching Allenheads. Its depth from the surface at this place will be about 200 yards.

The main part of the Halkyn tunnel in Flintshire is 2 miles 1256 yards in length, and the branch driven out to Rhosesmor mine intersected the vein at a distance of 809 yards, making a total of about $3\frac{1}{4}$ miles. The greatest depth from the surface is 230 yards, and the average depth in Halkyn Mountain about

215 yards. The length and depth of this adit are not remarkable; but the great quantity of water discharged is a point of considerable interest and importance. It is estimated that this adit is now discharging 15 million gallons or 66,000 tons of water in twenty-four hours, although the outflow is purely natural, for no mines are pumping water into it. It is now easy to understand that the Rhosesmor mine, though provided with powerful pumping machinery, was unable to cope with the springs it encountered.

In the United States the famous Sutro tunnel is an adit of which the main branch, 4 miles in length, reaches the great Comstock lode in Nevada at a depth of 1700 feet. The total cost of this tunnel, which was completed in nine years, is estimated to have been $7,000,000. The quantity of water running out daily in 1879 was 12,000 tons, at a temperature of 123° Fahr. at the mouth of the tunnel. All this water must otherwise have been pumped to the surface at a cost estimated at $3000 a day. The obstacles to progress were very great: not only was the heat extreme, but swelling ground was encountered which snapped the strongest timber. Thanks, however, to the untiring energy of Mr Adolph Sutro, the difficulties were at last successfully overcome, and this great work will long remain as a monument to his foresight, skill, and patient pertinacity.

The Atlantic-Pacific tunnel,[1] which was commenced in 1880, will pierce the heart of the Rocky Mountains under Grey's Peak, Colorado. It is being driven from both sides of the watershed, and will have a total length of 4⅝ miles from end to end.

Siphons. Siphons have been used for unwatering workings in special cases; but of course they will not act unless the barrier over which the water is raised is very decidedly less than 33 feet.

Winding machinery. When workings cannot be drained by tunnels or siphons it is necessary to raise the water mechanically, either to the surface or at all events to an adit through which it can flow away naturally. If the amount of water is not too considerable, it is often convenient to use the winding machinery and draw up the water in special buckets (*water-barrels*) or tanks. The bucket may be tilted over on reaching the surface, or it may be emptied by a valve at the bottom. This means of raising water is often adopted while sinking shafts, when it may be desirable to wait till the whole or a portion of the shaft is completed before putting in the final pumping machinery.

Pumps. The varieties of pumps used in mines are numerous. In small sinkings hand-pumps, either direct-acting or rotary, may be applied; steam-jet pumps on the principle of the Giffard injectors are also used; and pulsometers, though requiring a large expenditure of steam, have the advantages of being quickly fixed, of occupying little space, and of working with sandy or muddy water. They are capable, therefore, of rendering great services in special cases. When we come to the definitive machinery erected in large mines of considerable depth, we find that the prevailing types of pumps are few. They may be classified as follows:—(A) lifting and force pumps worked by rods in the shaft actuated by wind, water, or steam power; (B) force-pumps at the bottom of the shaft worked by steam, compressed air, or hydraulic pressure.

A. In describing the first method we have to consider the motive power, the rods, and the actual pumps themselves.

Windmills have the disadvantage, which is often fatal, that the power is not constant. By erecting an auxiliary steam-engine, which can be set to work if wind fails, this evil is overcome; and at the Mona mines in Anglesea a windmill pumps up water from a depth of 80 fathoms at the rate of upwards of 90 gallons per minute. As the site of the mine is breezy, there is wind enough to work the mill about one-half of the time.

Water-power was for a long period the principal agent employed in draining mines, and it is still of the greatest utility in many districts, reservoirs being constructed to collect and store the rainfall. Some idea of the scale upon which these works are conducted will be gathered from the following figures relating to the Harz mines. In 1868 there were "sixty-seven reservoirs covering an area of 604 acres, and having a storage capacity of 336,000,000 cubic feet."[2] The total length of the various leats, races, and other water-courses, including the six principal adits, is about 170 statute miles. The net power extracted is reckoned at 1870 horse-power, but less than one-fourth of this is used for pumping.

Water-power is applied to pumping machinery by water-wheels, turbines, and rotary or non-rotary water-pressure engines. Excepting the case of the latter, the rotary motion has to be converted into a reciprocating motion by a crank; and furthermore with turbines the speed must be reduced very considerably by intermediate gearing.

Overshot wheels are the commonest prime movers when pumps are worked by water-power; water-wheels are frequently constructed 40 or 50 feet in diameter, and at the Great Laxey mine, in the Isle of Man, one of the wheels is no less than 72 feet 6 inches in diameter and 6 feet in the breast. The power is conveyed from the water-wheel by a connecting rod to a bell-crank (*bob*) placed over the shaft; and when, owing to the contour of the ground, the wheel has to be placed at a distance, it is connected to the bob by the so-called *flat rods*, made of wood, bars of iron, or wire-rope, travelling backwards and forwards, and supported by pulleys or oscillating upright beams.

Water-pressure engines have the advantage of being able at once to utilize any amount of fall, and those which are direct-acting can be applied immediately to the main rod of the pumps.

Steam, however, is the power used *par excellence* in draining mines; indeed the first applications of steam-power were made for this purpose, and Watt's great inventions owed their birth to the necessities of mines which could no longer be drained by the water-power at their command.

Cornish engine. The principal type of engine is that known as the Cornish engine, which is a single-acting condensing beam engine working expansively. Its mode of action may be briefly described as follows. The steam is let in at the top of the cylinder and presses down the piston, which is connected with one end of a large beam, whilst the main rod of the pumps is attached to the other. When the piston has completed its course the equilibrium valve is opened by a cataract, and, the pressure on both sides of the piston being now equal, the weight of the pump rods, or rather the excess of their weight over that of the counterbalances, causes them to drop and force up the water from the mine by means of the plungers, which will be described immediately. Double-acting rotary engines working the pumps by cranks may also be met with.

The rod in the shaft, known as the *main rod* or *spear rod*, is usually made of strong balks of timber butted together and connected by *strapping plates* fastened by bolts. It serves to work either lifting-pumps or force-pumps, or both.

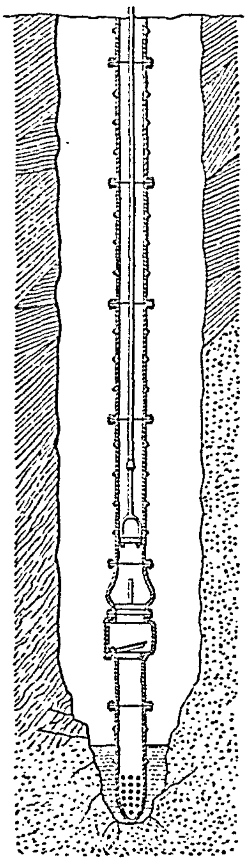


Fig. 87.

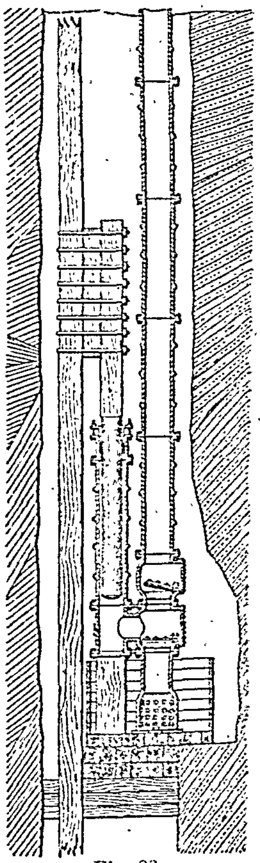


Fig. 88.

The lifting-pump, or drawing lift (fig. 87),[3] consists of the wind-bore, the clack-piece, the clack-seat piece, the working barrel

[1] *Mining and Scientific Press*, San Francisco, 1882, vol. xlv. p. 241.

[2] "Notes on the new Deep Adit in the Upper Harz Mines," by H. Bauerman, *Report of the Miners' Association of Cornwall and Devonshire*, 1868, p. 21.

[3] Michell and Letcher on "Cornish Mine Drainage," *Forty-Third Annual Report of the Royal Cornwall Polytechnic Society*, p. 211.

surmounted by pumps; and the bucket with its rod. The whole works like any ordinary pump, and needs no special explanation.

The force-pump used in mines, known as the plunger-pump, consists of a solid piston (*plunger*) (fig. 88)[1] working through a *stuffing-box* in a pump standing on the H-piece. This has a valve which communicates with the *windbore* resting in the cistern. Above the H-piece comes the *door-piece* with another valve, and then a series of pipes, generally of cast iron, but occasionally of wrought iron, constituting the column. The upward motion of the plunger, which is attached to the main rod, causes an inflow of water, which is forced into the column when the plunger descends. It is usual to fix a drawing lift at the bottom of the shaft, which raises the water into a first cistern, and thence a plunger forces it into a second cistern some 60 yards higher up; and it is continually forced up from cistern to cistern until it reaches the adit or the surface.

There are numerous important matters which require special attention, such as the valves, catches, balance-bobs, guiding arrangements for the rod in inclined shafts, the V-bobs, fend-off bobs, and running loops, which have to be used when there are bends in the shaft; but space will not permit of more than mere mention of these details.

Such then is the standard arrangement worked by steam or water power for pumping from mines. The great advantage of the system consists in the employment of the plunger, because it is simply necessary for the machine to raise a weight slightly greater than that of the water, which is forced up afterwards by the down-stroke of the rods. Leaks are readily discovered, and the stuffing-box can be easily screwed up as the packing wears; this is one great reason of the superiority of the plunger compared with a piston working in a barrel.

The modifications of this system relate more to the engines employed than to the actual pumps themselves.

The cylinder of the Cornish engine is sometimes reversed and stands over the shaft, the main rod being attached directly to the piston. This type of engine, known as the Bull engine in Cornwall, dispenses with the ponderous beam, but it has the great disadvantage of obstructing the mouth of the shaft. The use of two cylinders combined, as invented by Woolf, causes less strain upon the main rod and pumps (*pit-work*) and machinery generally, as the initial velocity of the piston is smaller and the engine starts with less jerk. The cylinders are placed side by side or one above the other.

Kley's engines.

Kley, of Bonn, has constructed engines on the Woolf system with steam acting on both sides of the pistons. He makes the excess of the weight of the rod over that of the counterbalances sufficient to raise only half the weight of the water and to overcome the friction; and then in the descending stroke the steam acts on the top of the piston and so makes up for the insufficiency in force of the rods. As the steam acts on both sides of the piston the same amount is consumed, it is true, but a smaller cylinder will do the work, and the original cost of the engine is lessened. The same engineer of late years has put up several pumping engines in Belgium, Germany, and France of 30 to 560 horse-power, with a fly-wheel which serves simply to regulate the stroke of the piston, so that the crank always stops before or after the dead point till the cataract starts another stroke. The engines are double-acting, with two cylinders and beam. The advantage of working with the fly-wheel is that the main rod and pumps are set in motion without the injurious jerk unavoidable with a Cornish engine worked at a high rate of expansion.

Guinotte's engine.

M. Guinotte, the well-known Belgian engineer, also adopts a fly-wheel, and the engines he has erected at Mariemont and elsewhere are single-acting rotary engines with one cylinder. The peculiarity of the fly-wheel is that he can weight it in any way he pleases; and he so overcomes the difficulty, which occurs in other rotary machines, of its being impossible to work them below a certain speed. His object has been to make the speed slow at the beginning and end of a stroke, so as to avoid the injurious shocks to the valves and machinery generally from sudden starts and stoppages. In order to make the main rod act by traction only and not compression, which may be advisable with iron rods, the plungers are sometimes reversed; whilst Kraft of Seraing has introduced the Rittinger pump, which consists of a hollow moving plunger with a valve inside, and a plunger case above it working over a hollow fixed plunger. By this arrangement both the up and the down stroke of the engine cause water to be forced up; and this pump is used with a double-acting rotary engine.

B. We must now speak of the second class of pumps, viz., force-pumps worked by steam, water-power, or compressed air at the bottom of the shaft.

The steam pumps are of very various descriptions,[2] but they mostly consist of one or two plungers, or rams, set in motion by a rotary or a non-rotary engine, which may or may not work with expansion and condensation. The plunger or ram is generally fixed directly on to the piston, and works in the same line, consequently the power is transmitted to the plunger with the least possible loss. The water is forced up the shaft in one long column. Engines and pumps of this kind are easily kept in order; all the parts are readily accessible. The miner is able to dispense with the heavy beam, the massive engine-house, the long main rod and its connexions and bobs, the various cisterns and plungers, and instead he has a compact and easily supervised machine and a simple line of pipes taking up but little space in the shaft; the pump can therefore be erected and set to work very quickly, and this is a matter of the utmost importance in emergencies. It is true that these direct-acting steam-pumps, even when worked by a compound engine, cause a greater consumption of coal than the Cornish engine; but, as a set off, there is the economy in first cost, erection, and repairs which has led to their adoption more especially in collieries. The steam is generated by boilers underground, or is conveyed from the surface in well-jacketed pipes.

If natural water-power is available water-pressure engines working the plunger directly are often employed, and indeed such water-power may be created artificially for use in workings where steam-power is objectionable on account of the heat. There are other reasons too for employing water for transmitting power; where the length of the rods is very great, and they have to be worked quickly, there is a great liability to breakages; in order to overcome these difficulties at the mines on the Comstock lode, Mr Joseph Moore[3] uses a steam-engine at the surface to work an hydraulic accumulator, and then by pipes conveys the water under pressure to hydraulic engines working plungers. These are fixed at 2400 feet from the surface, and force the water in one column, 813 feet high, to the level of the Sutro tunnel. The exhaust water is returned to the surface in pipes and used over again. The pumps are now raising 1600 to 1700 gallons per minute.

Where compressed air is being supplied to a mine for drilling and winding purposes, it is often convenient to employ it, by means of direct-acting pumps, such as are generally used with steam, for the drainage of small temporary sinkings; and occasionally large pumps raising considerable quantities of water are worked in this way.

11. *Ventilation and Lighting.*—The composition of the air of the atmosphere is about one-fifth by volume of oxygen and four-fifths of nitrogen, with a little carbonic acid gas; more exactly, the standard amount of oxygen may be taken at 20·9 per cent., and that of the carbonic acid gas at 0·03 per cent. The atmosphere of mines is subject to various deteriorating influences: not only do noxious gases escape from the rocks into the underground excavations, but also the very agents employed in the execution of the work itself pollute the air considerably.

Deleterious gases.

The dangerous emanations of fire-damp in collieries have been already described (COAL, vol. vi. p. 72); and with reference to this gas it is simply necessary to say that its presence is not entirely confined to coal mines. Large quantities have been observed in Silver Islet mine,[4] Lake Superior, where several explosions have occurred, whilst small quantities are met with in the stratified ironstone of Cleveland, and also in the Cheshire salt mines; jets of the gas may be seen constantly burning in the salt mine at Bex in Switzerland; a little has been noticed also in lead mines in Wales and Derbyshire. In the Sicilian mines the amount given off by the black carbonaceous shales inter-stratified with the sulphur beds is sufficient to cause dangerous explosions. It has been pointed out (vol. vi. p. 72) that carbonic acid gas exudes from coal;[5] it escapes also from some mineral veins. At the lead mines of Pontgibaud in central France it is so abundant that special fans have to be provided for getting rid of it; very distinct issues of this gas may be observed at the Foxdale mines in the Isle of Man, and in the Alston Moor district it is not

1 Michell and Letcher on "Cornish Mine Drainage," *Forty-Third Annual Report of the Royal Cornwall Polytechnic Society*, p. 211.

2 Stephen Michell, *Mine Drainage*, London, 1881.

3 *Trans. Inst. Engineers and Shipbuilders in Scotland*, 1882.

4 *Engineering and Mining Journal*, vol. xxxiv. p. 322.

5 A. Schondorff, "Untersuchung der ausziehenden Wetterströme in den Steinkohlenbergwerken des Saarbeckens," *Zeitschrift für das Berg-, Hütten-, und Salinen-Wesen im Preussischen Staate*, vol. xxiv. p. 73; and Cl. Winkler, "Die chemische Untersuchung der bei verschiedenen Steinkohlengruben Sachsens ausziehenden Wetterströme und ihre Ergebnisse," *Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen auf das Jahr* 1882, p. 65.

uncommon. This gas is likewise given off in the Sicilian sulphur mines, where also the highly poisonous sulphuretted hydrogen is of frequent occurrence, the water in the workings being often saturated with it. Small quantities of mercurial vapour occur in quicksilver mines.

Products of respiration, blasting, &c.

Such then are the principal gases which naturally pollute the atmosphere of mines, and have to be swept out by ventilation. In addition to these we have the products of the respiration of the men and animals in the pit, and those due to the combustion of candles or lamps, and the explosion of gunpowder, dynamite, &c.

Dr Angus Smith[1] reckons that two men working eight hours, and using ½ lb of candles and 12 oz. of gunpowder, produce 25·392 cubic feet of carbonic acid (anhydride) at 70° F.,—viz., 10·32 by breathing, 12·276 by candles, and 2·796 by gunpowder.

The products of the explosion of gunpowder have been carefully studied by Captain Noble and Sir Frederick Abel, and the following figures, showing proportions by weight, are copied from the valuable paper[2] containing the results of some of their researches:—

	Curtis & Harvey's No. 6 Gunpowder.	Mining Powder.
Total solid products	57·74	47·04
Total gaseous products	41·09	51·35
Water	1·17	1·61
	100·00	100·00

The solid residue of the mining powder consisted mainly of potassium carbonate, potassium monosulphide, and sulphur. The percentage composition by volume of the gas produced was:—

	Curtis & Harvey, No. 6.	Mining Powder.
Carbonic anhydride	50·22	32·15
Carbonic oxide	7·52	33·75
Nitrogen	34·46	19·03
Sulphuretted hydrogen	2·03	7·10
Marsh gas	2·46	2·73
Hydrogen	3·26	5·24
	100·00	100·00

The volume (calculated for a temperature of 0° C. and barometer 760 mm. of mercury) of permanent gases generated by the explosion of 1 gramme of dry powder is—

Curtis & Harvey, No. 6	241·0	cubic centimetres.
Mining	360·3	,, ,,

MM. Sarrau and Vieille have communicated to the Academy of Sciences[3] the results of their researches concerning the decomposition of certain explosives, and more particularly gun-cotton and nitrated gun-cotton. The following table shows, in litres, the volume (at 0° C. and 760 mm. of mercury) of each of the gases per kilogramme of the substance exploded in a closed vessel:—

Kind of Explosive.	CO.	CO_2.	H.	N.	O.	C_2H_4.	HS.	Total.
Pure gun-cotton	234	234	166	107	...	...	...	741
Gun-cotton and nitrate of potash (50 per cent. of each)	...	171	...	109	45	...	...	325
Gun-cotton (40 per cent.) and nitrate of ammonia (60 per cent.)	...	184	...	211	6	...	...	401
Nitro-glycerin	...	295	...	147	25	...	...	467
Ordinary blasting powder	64	150	4	65	...	4	17	304

If, however, the explosive is decomposed at a pressure approaching that of the atmosphere, the volumes (again at 0° C. and 760 mm. of mercury) are very different, as shown below:—

Kind of Explosive.	NO_2	CO.	CO_2.	H.	N.	C_2H_4	Total.
Pure gun-cotton	139	237	104	45	33	7	565
Gun-cotton and nitrate of potash (50 per cent. of each)	71	58	57	3	7	...	196
Gun-cotton (40 per cent.) and nitrate of ammonia (60 per cent.)	122	65	103	12	112	...	414
Nitro-glycerin	218	162	58	7	6	1	452

When explosives are decomposed in this way they liberate nitric oxide and carbonic oxide, and the analyses of MM. Sarrau and Vieille confirm the practical experience of miners, who complain greatly of noxious fumes when, owing perhaps to a bad detonator, a charge of dynamite or tonite fails to explode properly.

The air of mines is finally deteriorated by organic matter contained in the exhalations of the men and animals employed and in the products of decaying timber, by dust, and by the solid particles constituting the smoke of explosives. It must be recollected also that the injury to the air is not confined to the addition of the gases and substances just mentioned; but the proportion of oxygen is diminished by the combustion of candles, by respiration, the decay of timber, and decomposition of some minerals such as iron pyrites. Dr Angus Smith[4] sums up the results of his analyses of the air of British metal-mines as follows:—

	Percentage by volume.
Oxygen, average of 339 specimens	20·26
,, of ends	20·18
,, other parts	20·32
,, in currents	20·65
,, in large cavities	20·77
,, just under shafts	20·42
,, in sumps	20·14
Carbonic acid	0·785

He considers air with 20·9 per cent. oxygen as normal, and air with proportions between that and 20·6 as impure; and where the percentage of oxygen descends below 20·6 he calls the air exceedingly bad. According to these standards, only 10·67 per cent. of the samples showed the air to be normal or nearly so; 24·69 per cent. were decidedly impure; whilst 64·63 per cent. or nearly two-thirds of the samples were exceedingly bad. The amount of oxygen in one specimen was as low as 18·52 per cent., whilst the carbonic acid often exceeded 1 per cent. and in several instances 2 per cent. It is evident that twenty years ago the ventilation of British metal mines was anything but satisfactory, and even now there is room for improvement.

Having explained the reasons why the air of mines must be constantly renewed, we must now point out how this desirable end is effected.

Systems of ventilation.

Two systems are employed,—natural ventilation and artificial ventilation; but, as both systems have been described (COAL, vol. vi. p. 70), little remains to be said here, especially as the ventilating machines in metalliferous mines generally cannot for one moment be compared with the powerful appliances employed in collieries. In vein-mining there are generally many more shafts than in collieries, and natural currents are set up which are often considered sufficient for ventilating the mines; nevertheless, the advanced workings, such as the ends, rises, and winzes,—in fact all workings in the form of a *cul-de-sac*,—are likely to require special means of ventilation as soon as they proceed a little distance from the main air-current.

The means of ventilating a drift or heading are various. If a natural or artificial draught exists at the mouth of the drift, it may be diverted by an upright partition (*brattice*), or an air-way may be constructed along the roof or floor by a horizontal partition of planks (*air-sollar*) (fig. 89). In this way a sufficient supply is secured at the end or fore-breast.

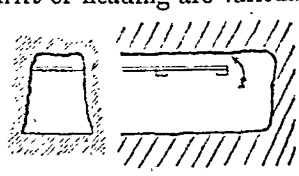


Fig. 89.

The water-blast is another simple appliance; it is precisely the same as the well-known tromp, and it blows a current of air through square pipes made of boards, or better through cylindrical pipes of sheet zinc. The fall of water may be applied by Williams's water-jet, shown in fig. 90. The jet of water acts like an injector, and creates a powerful current.

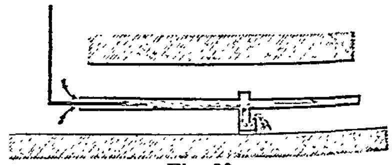


Fig. 90.

Small fans driven by boys, or better by small water-wheels or other machinery, are frequently applied, and the

[1] *Report of the Commissioners Appointed to Inquire into the Condition of all Mines in Great Britain to which the Provisions of the Act 23 & 24 Vict. c. 151 do not apply*, Appendix B., p. 224.

[2] "On Fired Gunpowder," Captain Noble and Mr F. A. Abel, *Phil. Trans.*, 1880, p. 278.

[3] "Recherches expérimentales sur la décomposition de quelques explosifs en vase clos; composition des gaz formés," *Comptes Rendus*, 1880, pp. 1058 and 1112.

[4] *Op. cit.*, p. 222.

Harz blower (*duck machine*, Cornwall) (fig. 91) is not uncommon. This is merely an air-pump of very simple construction which is worked by the main rod of the pumps, and can be arranged so as to exhaust the foul air or force in fresh air.

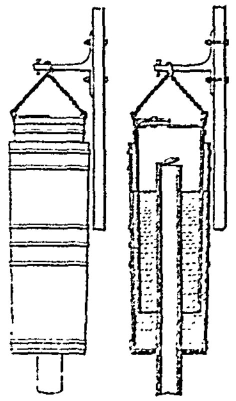


Fig. 91.

In working in blasting ground, boring-machines driven by compressed air are becoming more and more largely used every day, and the exhaust air escaping from the machines is invaluable for ventilation. At the same time, on account of volley firing, the quantities of deleterious gases generated in a short space of time are very considerable; and, in order to get rid of them speedily, the compressed air may be utilized for working a Körting aspirator or the somewhat similar ventilator of Mr Teague, a jet of compressed air turned into a ventilating pipe, which creates an exhaust (fig. 92[1]). Naturally this ventilator is merely brought into play at the time of blasting, and while the boring machinery is out of use. When compressed air is being supplied on a large scale to a mine for boring and winding machinery, it is often convenient to convey it by a small gas-pipe to working places in which the ventilation is inadequate. Of course, in one sense, it is very uneconomical to compress air to a pressure of 60 or 70 ℔ to the square inch for ventilating purposes only; but, where compressing machinery is always at work on the mine, it may be better to be a little wasteful of cheap power at the surface than to go to the greater expense of having a man or boy to work a fan underground.

Aspirators.

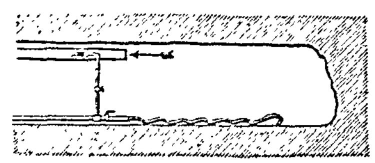


Fig. 92.

Lighting.

Mines are lighted by lamps, torches, candles, and electricity. The subject of safety lamps for fiery mines has already been discussed (see COAL, vol. vi. p. 72), and consequently the question of illuminating mines may be treated in a very summary manner.

Lamps vary very much in shape and size. The Sicilian miner has a mere shallow cup of unglazed pottery; the Saxon a small tin or brass lamp in a wooden box lined with tinplate and open in front. In the Harz the miner prefers a heavy flat iron lamp with a hook by which it is stuck into the timber or any crack in the rocks; in France, northern Italy, and parts of Spain, the iron lamp is lenticular in shape and also suspended by a hook. In Scotland, and parts of Germany and the United States, a small tin lamp of the shape shown in fig. 93 is very common; the hook enables it to be carried on the hat while climbing ladders, and to be fixed up underground. Olive oil and rape oil are burnt in these lamps; petroleum lamps are employed occasionally.

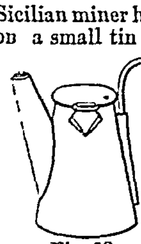


Fig. 93.

The miners of England and Wales still cling to the tallow candle; and when surrounded by a lump of clay it can easily and quickly be fixed in the working place or carried upon the hat when climbing. Gas brought down from the surface answers for illuminating large excavations, such as on-setting places and engine-rooms.

Up to the present time the electric light has been but little used underground on account of its want of portability, and the smallness of the spaces requiring illumination. Very often a few men only are employed in each working place, and consequently the expense incurred in fixing and shifting the lamps and maintaining them alight would be out of proportion to the value of the work executed. However, an incandescent electric lamp has been invented weighing only 10 ℔, which gives the light of three candles for six hours, and it may be reasonably expected that improvements will be made which will render the electric light more available for underground purposes than it is at present. When the area requiring illumination is large, an arc-lamp may be used with advantage.

Among the first successful applications of electric lighting to underground excavations may be mentioned that of M. Blavier at the Angers slate quarries.[2] In the year 1879 he fixed two Serrin lamps in one of the large underground chambers with an area of 2400 square yards, and he found that they gave light enough for all the men at work. The total cost, reckoning everything, viz., coal, carbons, repairs, labour, depreciation of plant, and interest on capital, is 50 francs per day; the gas formerly in use cost 54 francs a day and gave much less light. It is evident, however, that the arc lights can only be applied with advantage in special cases where a large number of men are concentrated in one working area which can be illuminated from one or two points.

The large chambers in the salt mine of Maros-Ujvár in Hungary have been regularly lighted up by electricity since 1880. The cost is somewhat greater than that of the tallow, oil, or petroleum formerly in use; but, on the other hand, the illumination is better, the men can do more work and are more easily supervised, whilst the air of the mine is not deteriorated by the products of combustion of the lamps.[3]

Means of access.

12. *Means of Descending into and Ascending from Mines.*—Where mines are worked by adit-levels the men naturally walk in along the ordinary roadways; such mines, however, are exceptional, and the men generally have to climb down and up by ladders, or are raised and lowered by machinery. The means of access to and from workings may be classified as follows:—(1) steps and slides; (2) ladders; (3) cages; (4) man-engines.

Steps.

If a lode or seam is inclined at an angle or 40° or 50° from the horizon, steps may be cut in the floors of the deposit if it is firm enough, or wooden stairs may be put in with a hand-rail. Even with higher dips steps may be arranged by directing them in a line intermediate between the dip and the strike. In speaking of conveyance underground, reference has already been made to the practice of carrying sulphur ore in Sicily and slate in Germany up to the surface by steps; and steps may be found in other foreign mines and occasionally in Great Britain. They are much less fatiguing than ladders placed so flat that part of the weight of the body rests upon the arms. In some of the Austrian salt mines the men descend by wooden slides inclined at angles varying from 30° to 50°, flattening at the bottom to destroy the velocity gradually; the ascent is effected by steps.

Slides.

Ladders.

Ladders are very largely used in metal mines all over the world, but they vary a good deal in different countries. The ladder consists of two sides and a series of rungs (*staves*, Cornwall). The sides are usually made of wood, and the rungs of wood or iron. The distance between the rungs is important; 10 inches from centre to centre is sufficient, for climbing upon ladders with the rungs 12 inches apart is decidedly more fatiguing. On the Continent wooden rungs are commoner than iron ones, and oak is preferred. Sometimes the wooden staves, instead of being round, are flat, so as to stand more wear, and iron sides may be seen in places where dry rot is very bad. Platforms should be fixed at short intervals, not exceeding 3 or 4 fathoms in perpendicular shafts, so as to prevent falls from having fatal consequences.

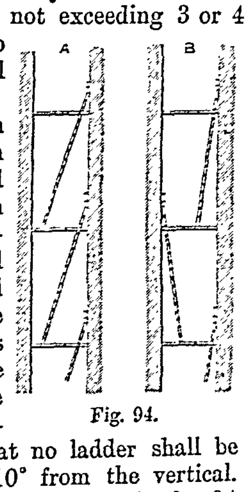


Fig. 94.

In many cases sufficient attention is not paid to the angle of inclination of the ladders. A ladder is climbed with the least fatigue when the person uses his arms simply to steady himself, and is not compelled to pull himself up by them, as on a vertical ladder, or to support much of the weight of his body by them, as happens with a very flat one. The best angle is about 20° from the vertical, and in Belgium the authorities have very wisely decreed that no ladder shall be inclined at an angle of less that 10° from the vertical. Furthermore, of the two arrangements shown in fig. 94

[1] *Trans. Roy. Geol. Soc. Cornwall*, vol. x. p. 142.

[2] M. Blavier, "L'Éclairage électrique aux Ardoisières d'Angers," *Annales des Mines*, ser. 7, vol. xvii., 1880, p. 5.

[3] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1882, No. 25, p. 296.

A is better than B, because it not only affords a greater inclination for the ladders, but also renders it less likely that a man will drop through the opening (*manhole*) in the platform (*sollar*) if he loses his hold and falls. These may seem trifling matters; but, leaving aside the question of safety, the economy derived from fixing the ladders at the best inclination is by no means small. To make this apparent we must recollect the depths to and from which men have to climb, viz., 300, 400, and even 500 yards. It is important, therefore, to save every unnecessary expenditure of energy, which, though trifling for one ladder, becomes considerable when repeated a great number of times. When a mine has reached a depth of 200 yards, and *a fortiori* when it exceeds it, mechanical appliances should be introduced for raising and lowering the men, because time and strength are wasted by climbing. Medical men also are agreed that excessive ladder-climbing is injurious to the health of the miner. Therefore, both upon hygienic and financial grounds, one of the first thoughts in working a mine should be the conveyance of the men up and down the shafts by machinery with the least possible fatigue.

Cages. In collieries and other mines worked by perpendicular shafts, it has long been customary to raise and lower the men by the ordinary winding machinery already described. In the United Kingdom it is necessary that guides should be used if the shaft exceeds 50 yards in depth; safety-catches and disengaging hooks (COAL, vol. vi. p. 75) are frequently applied for the purpose of preventing accidents. The simplicity of this method of ingress and egress naturally renders it popular, and statistics prove that, where proper precautions are used, it is exceedingly safe.

Man-engines. The first man-engine was put up in the Harz in 1833, and nine years later a similar machine was fixed in Tresavean mine in Cornwall. Since that time this very useful means of conveying workmen up and down shafts has been resorted to in other mining districts, and especially in Belgium and Westphalia.

Two kinds of man-engine are in use, the double-rod machine and the single-rod machine. The double-rod or original man-engine consists of two reciprocating rods like the main rods of pumps, carrying small platforms upon which the men stand. The stroke is from 4 to 16 feet, and the little platforms are so arranged that they are always opposite each other at the beginning and end of each stroke.

Figs. 95 and 96 represent the rods in the two final positions. A man who wishes to descend steps upon platform *b* (fig. 95); the rod B goes down, and A goes up, so that *b* (fig. 96) is brought opposite *c*. The man steps across from *b* to *c*, and then the rod A makes a down-stroke, B an up-stroke. Platform *c* is now opposite *d* (fig. 95), and the man again steps across; and thus, by constantly stepping from the rod as it completes its down-stroke, the man is gradually conveyed to the bottom of the shaft. By reversing the process, or, in other words, by stepping off on to the opposite platform as soon as the rod has completed its up-stroke, the man is raised to the surface, without any fatigue beyond that of the very slight effort of stepping sideways. If each rod makes four up and down strokes of 10 feet each per minute, the rate of ascent or descent will be 80 feet per minute.

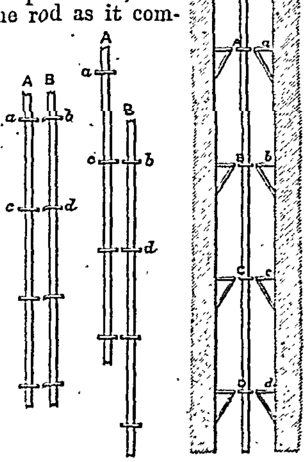


Fig. 95. Fig. 96. Fig. 97.

The single-rod man-engine has one rod carrying steps, whilst fixed platforms are arranged in the shaft so as to correspond exactly with them (fig. 97). If a man wants to go down, he steps on to A when the up-stroke is completed; the rod goes down and A is brought down opposite to the fixed platform *b*, on to which he steps off. He then waits on *b* until the rod has finished its up-stroke. B is brought opposite *b*; he steps on to B, the rod goes down and he is brought opposite *c*, where he steps off again and waits. By reversing the operation he is gradually lifted to the top of the shaft. The single-rod engine may be used by men going up while others are going down, provided that there is sufficient room upon the fixed platforms (*sollars*). The best plan is to have sollars right and left, as shown in the figure, and then the ascending men step off to the left, for instance, while the descending men take the right-hand sollars. The ascending man steps on to the man-engine as soon as the descending man steps off, and so the rod may be always carrying men up or down. The usual stroke in Cornwall is 12 feet, and there are from three to five or six strokes a minute. With five strokes the men descend 10 fathoms a minute, or in other words a descent or ascent of 300 fathoms occupies half an hour. The reciprocating motion is best obtained from a crank, because in this case the speed is diminished gradually at the dead points, and the danger of an accident in stepping off and on is thereby diminished; man-engines, however, are sometimes driven by direct-acting engines.

Man-engine rods are constructed of wood or iron; and at Andreasberg in the Harz each rod is replaced by two wire ropes. Like a pump rod the man-engine rod requires proper balance bobs and catches, and for the safety of the men a handle is provided at a convenient height above each step.

The man-engine has one great advantage over the cage, which consists in the fact that it can be safely applied in inclined and even crooked shafts; and it is for this reason that man-engines have been adopted in many metal mines unprovided with vertical shafts.

Careful comparisons as regards safety of travelling have been made in Prussia between ladders, man-engines, and cages. The average accidental death-rate is shown by the accompanying table, which gives averages for a period of ten years, 1871 to 1880:—

	Ladders.	Man-engines.	Cages.
Average annual number of men travelling.	73,942	7,191	64,071
Total number of persons killed..............	75	41	74
Average annual death-rate per 1000........	0·101	0·570	0·115

The table shows that the cage is nearly as safe as ladders. In reality, if the actual distance travelled were taken into account, the cage would appear to be safer, because we may fairly assume that the mines in which men are hoisted by cages are on the whole very much deeper than those in which men ascend and descend by ladders. The man-engine appears to be decidedly more dangerous than either the cage or ladders. Here again a distinction requires to be made between the single-rod and the double-rod machines, and the Prussian statistics include many of the latter. It will be readily understood that a fall in a naked shaft with few fixed platforms is much more likely to be fatal than a fall in the shaft of a single-rod man-engine which is closed with the exception of the manhole at intervals of 12 feet. The Belgian *warocquères* are rendered safer than the Harz or Saxon man-engines by having a railing round the back of each platform on the rod. Some of the double-rod machines are made with large platforms so that two persons can stand on them, one going up and the other going down, or both travelling in the same direction. The use of double-rod man-engines has been entirely abandoned in the United Kingdom. The death-rate from accidents on man-engines in Cornwall and Devon during the nine years 1873 to 1881 was 0·17 per 1000 persons using them, whilst the annual death-rate per 1000 persons using ladders was slightly higher, viz., 0·19. If the actual distance travelled were taken into account, the scale would turn more decidedly in favour of the man-engine.

The cost of raising and lowering men by the man-engine is not great. At Dolcoath, a tin mine in Cornwall approaching 400 fathoms in depth (see figs. 62, 63), it is reckoned that 1½d. per man per day covers all expenses, including interest upon the capital expended and depreciation of plant.

13. *Dressing or Mechanical Preparation of Ores.*—In a large number of cases the mineral, as it is raised from the mine, is not ready for sale. It usually requires to be subjected to mechanical processes whereby the good ore is entirely or partly freed from valueless veinstone. These processes, which in a few special instances are aided by calcination in furnaces, are known as the dressing or mechanical preparation of the ores. As a rule the valuable ore is specifically heavier than the veinstone, and most of the separating processes are based upon the fact that the heavy particles of ore will fall in water more quickly than the light particles of veinstone. Dressing of ores.

The processes of mechanical preparation may be classified as follows:—(1) washing and hand-sorting; (2) disintegration, or reduction in size; (3) classification by size or by equivalence; (4) concentration.

(1) Sometimes the ore coming from the mine requires simply to be freed from adhering particles of clay in order Washing.

to be rendered fit for sale, at other times the washing is necessary as a preliminary process previous to sorting by hand. The operation is performed either by raking the ore backwards and forwards upon a grating under a stream of water, or in a box containing water, or, thirdly, by means of an inclined revolving iron drum worked by hand or any other motive power. The machines used for this purpose, known as washing trommels, are revolving cylinders or truncated cones of sheet-iron provided with teeth inside. The ore is fed in at one end, is subjected to the action of a stream of water, and is discharged at the other end.

The *stuff*, *i.e.*, the mixed ore, veinstone, and country rock, having been cleansed, it is now possible to make a separation by hand. Women and children are generally employed for this work, as their labour is cheaper and their sight sharper than that of men. The stuff is spread out on a table, and various classes are picked out according to the nature of the products furnished by the mine. Thus in a lead mine we may have—(*a*) clean galena, (*b*) mixed ore, *i.e.*, pieces consisting partly of galena and partly of barren veinstone, (*c*) barren veinstone and country rock. This is a most simple case; very frequently we have to deal with a vein producing ores of two metals, especially in the case of lead and zinc, and then the classification into various qualities becomes more complicated.

Disintegration. (2) Reduction in size is necessary for two reasons. Even when an ore is sufficiently clean for the smelter, the large lumps are often crushed by the miner for the sake of obtaining a fair sample of the whole, or supplying a product which is at once fit for the furnace. The chief reason, however, for disintegration lies in the fact that the particles of ore are generally found enclosed in or adhering to particles of barren veinstone.

The disintegration is effected by hand or by machinery. Large blocks of ore and veinstone are broken by men with large sledge hammers, and the reduction in size is continued very often by women with smaller hammers. Sometimes the blow of the hammer is directed so as to separate the good from the poorer parts, and hand-picking accompanies this process, called *cobbing*. Ore may be crushed fine by a flat-headed hammer (*bucking iron*) on an iron plate.

The machines used for reducing ores to smaller sizes are very numerous; here it is impossible to do more than briefly call attention to those most commonly used. These are stone-breakers, stamps, rolls, mills, and centrifugal pulverizers.

Stone-breaker. The stone-breaker, or rock-breaker, is a machine with two jaws, one of which is made to approach the other, and

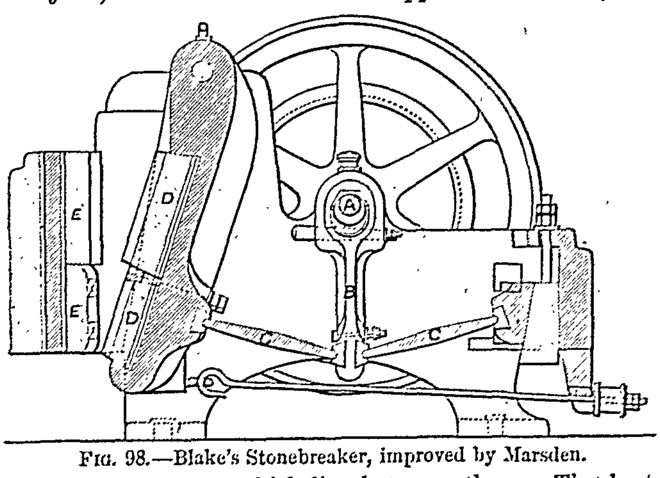


Fig. 98.—Blake's Stonebreaker, improved by Marsden.

so crack any stone which lies between them. The best-known stone-breaker is the machine invented by Blake, which has rendered inestimable services to the miner for the last twenty years, and the introduction of which constituted a most important step in advance in the art of ore-dressing. Its mode of action is very simple. When the shaft A (fig. 98) revolves, an excentric raises the "pitman" B, and this, by means of the toggle-plates C, C, causes the movable jaw D to approach the fixed jaw E by about $\frac{3}{8}$ inch at the bottom. When the pitman descends the jaw is drawn back by an india-rubber spring. The jaws are usually fluted, the ridges of one jaw being opposite the grooves of the other, and they are so constructed that the wearing parts are quickly and easily replaced.

Mr Marsden of Leeds has lately introduced a pulverizer, constructed on the principle of the stone-breaker, which will reduce large stones to the finest powder in one operation. The moving jaw has an up-and-down as well as the old backwards-and-forwards motion, and the stones are first cracked and then ground by the double action.

Stamps are pestles and mortars worked by machinery. Stamps. The construction of the modern California stamp mill with revolving heads is explained in Gold, vol. x. p. 747, and the description need not be repeated. In Cornwall the older form with rectangular heads still prevails.

It is impossible to give any correct average figures representing the work done by a stamping mill, because this varies with the hardness of the stuff treated and the fineness to which it must be reduced. However, it is usual in Cornwall to reckon 1 ton of tinstuff and in California 1 to $1\frac{1}{4}$ ton of gold quartz stamped per horse-power in twenty-four hours.

Stamps are principally used in dressing the ores of gold, silver, and tin, but are occasionally employed for those of copper and lead. The stamps described at vol. x. p. 747 act simply by gravity. Another form, which has met with favour in the Lake Superior district, is the direct-acting or Ball stamp, which works like a steam hammer, the blow of the head being assisted by the pressure of steam. At the Calumet and Hecla Mill, Lake Superior, each Ball stamp is capable of crushing 130 tons in twenty four hours. In a third kind of stamps, the heads are lifted by a crank and the power of the up-stroke compresses a cushion of air (pneumatic stamps) or a spring, storing up power which makes the down-stroke strike a heavier blow.

Revolving rolls were introduced in the west of England Rolls. in the early part of the present century to replace *bucking* by hand. The machine, now often known as the Cornish crusher, consists of two cast-iron or steel cylinders which revolve towards each other, whilst at the same time they are kept pressed together by levers or springs. The cylinders or rolls are generally from 18 inches to 2 feet or 2 feet 8 inches in diameter and 12 to 22 inches wide.

Stone mills constructed like flour mills are employed in Mills. some countries for reducing ores to powder; and the *arrastra*, which consists of heavy stones dragged round upon a stone bed, has rendered good service in grinding and amalgamating gold and silver ores, in spite of its being slow and cumbersome. Edge-runners (Chilian mills) also deserve mention.

Iron mills, known as *pans*, with grinding surfaces made of chilled cast-iron and arranged so that they can be quickly and easily replaced when worn out, are greatly in vogue in the United States for the treatment of ores of gold and silver; the ore delivered to them is already finely divided, and they are intended, not only still further to reduce the size of the particles, but also and more especially to effect the amalgamation of the precious metals with quicksilver. The pulverizers used in Cornwall for grinding grains of tin ore with a little waste still adhering to them are also iron mills.

The centrifugal pulverizers are machines by which the

Centrifugal pulverizers. pieces of ore are thrown with great velocity against bars or arms, or against each other, and so reduced to powder; in other machines iron balls or iron rollers are whirled by centrifugal force against an iron casing and grind any mineral contained inside it. These pulverizers are much less used than stone-breakers, stamps, and rolls for the disintegration of metallic ores.

Classification of ores. (3) Classification of a crushed ore into sizes is absolutely necessary in some cases and advisable in others, because the subsequent concentration is dependent upon the fall of the particles in water, as will be presently explained. Classification by size is effected by sieves. Hand sieves and flat sieves placed one above the other have been superseded at most dressing establishments by cylindrical or conical revolving screens known as trommels. These screens are made of wire web or of perforated sheets of metal, and they are often arranged so as to discharge one into the other, so that the ore from a crusher can quickly be separated into classes of various sizes.

With sizes of less than 1 millimetre ($\frac{1}{25}$ inch) trommels are no longer employed, and recourse is had to the so-called separators or classifiers. These are boxes in the shape of inverted cones or pyramids into which the finely crushed ore is brought by means of a current of water; a jet of clean water is often made to rise up in the bottom; the larger and the specifically heavier particles fall and are discharged with a stream of water at or near the bottom, whilst the smaller and specifically lighter particles flow away at the top. The separators do not effect a true classification by size; they merely cause a division by *equivalence*, a term which will be explained immediately.

Concentration. (4) We now have to deal with the enriching of the ore, or the concentration of the valuable particles into as small a bulk as is economically advantageous. The concentration is generally brought about by the fall of the particles in water. Occasionally the fall in air is utilized; mercury is employed as a collecting agent in the case of gold and silver, and in a few instances magnetism can be applied.

The concentration in water depends upon the difference in specific gravity of the valuable ore and the waste veinstone or rock. A piece of galena with a specific gravity of 7·5 sinks to the bottom more quickly than a similar piece of quartz, the density of which is only 2·6. Nevertheless a large piece of quartz may fall to the bottom as quickly as a small piece of galena. Particles which have equal velocities of fall, though differing in size and specific gravity, are said to be *equal-falling*, or *equivalent*. P. von Rittinger shows that a sphere of quartz of $\frac{1}{4}$ inch in diameter would sink in water exactly as quickly as a sphere of galena of $\frac{1}{16}$ inch in diameter, and these two particles are therefore equal-falling. Consequently, before we can separate properly by water it is necessary to classify the particles by size, so that equivalence shall not prevent a separation or lessen its sharpness. It is nevertheless true that in the early part of the fall of equivalent grains the influence of the specific gravity preponderates, and the denser particles take the lead; therefore, by a frequent repetition of very small falls, particles which have not been closely sized may still be separated.

Jiggers. The principal machine for concentrating particles of sizes ranging between 1 inch and $\frac{1}{50}$ inch is the jig or jigger. The hand jigger is merely a round sieve which is charged with the crushed ore and then moved up and down in a tub full of water. The particles gradually arrange themselves in layers, the heaviest on the bottom and the lightest at the top. On lifting out the sieve the light waste can be skimmed off with a scraper, leaving the concentrated product below ready for the smelter or for further treatment. Similar sieves worked by machinery were for a long time employed in dressing establishments, but the introduction of the improved continuous jiggers has led to their abandonment in all works of any importance. The continuous jigger is one of the most useful dressing machines of the present day. It consists of a box or hutch divided by a partial partition into two compartments; in one is fixed a flat sieve *s* (fig. 99), which carries the ore, and in the other a piston *p* is made to work up and down by means of an excentric. The hutch being full of water, the movement of the piston causes the water to rise up and fall down through the ore, lifting it and letting it fall repeatedly. The effect of these frequent lifts and falls is to cause a separation of the previously sized ore into layers of rich mineral at the bottom, light waste at the top, and particles of ore mixed with waste in the middle.

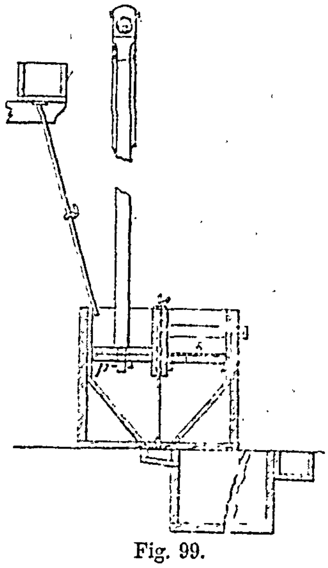


Fig. 99.

The great value of these jiggers is the continuous discharge of the products without stoppages for their removal. Several methods are in vogue, viz., the end discharge, the central discharge, and the discharge through the meshes of the sieve. With the first, the enriched product lying at the bottom of the sieve passes out through openings at the end of the jigger, and the amount escaping is governed by an adjustable cap or shutter, by which the size of the openings can be increased or diminished at pleasure; the middle product can be discharged by openings placed a little higher up, whilst the waste is washed over the top of the end of the jigger at each pulsation. Very often a first sieve simply separates a concentrated product and discharges the poorer product into a second sieve, where a similar separation is effected. With the central discharge, a pipe is brought up through the bottom of the sieve, and the size of the opening for the escape of the concentrated ore is regulated by a cylindrical cap which can be raised or lowered by a screw. The discharge through the sieve is especially adapted for the finer products from the crusher, though it is also used in some cases for grains up to $\frac{1}{4}$ inch in diameter. The mesh of the sieve is chosen so that the particles under treatment will just pass through, but above the sieve a layer of clean ore is placed which prevents anything but the heavier particles from being discharged. The pulsations of the water, as before, cause a separation into layers, and the heavy rich particles find their way through the bed and drop into the hutch, whence they can be drawn off through a hole at pleasure. The poorer part passes over a simple sill at the end of the sieve, or to a second sieve if necessary. Three or four sieves are occasionally arranged in a row in one machine.

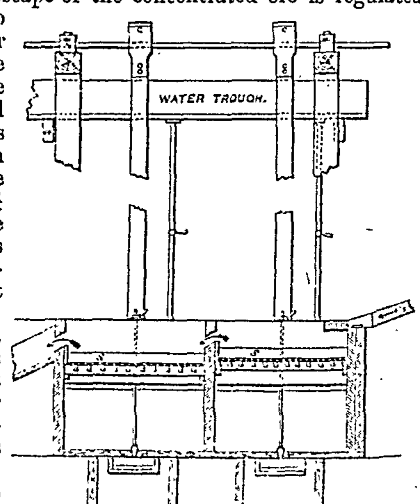


Fig. 100.

Fig. 100 is a section through the two sieves of a Harz sand jig. The pistons act in the manner explained by fig. 99.

The smaller sizes are concentrated by a variety of machines. The action of many of them is based upon the behaviour of particles carried down an inclined plane by a thin stream of water. If the gradient of the plane and the strength of the thin current are properly arranged, the denser particles will be deposited and the specifically lighter ones washed away, although they may be *equal-falling* if allowed to settle in deep water.

The principal machines for concentrating fine sands and slimes are the frame, rotating frame, percussion frame, side-blow percussion frame, revolving belt and Frue vanner, the hand buddle, the round buddle, and the keeve.

Frames. The frame is simply an inclined wooden table upon which a thin deposit is formed by the sheet of ore-and-waste-bearing water which is made to flow over it gently. The stream is then stopped and the deposit washed off by hand or automatically, and collected in pits for subsequent retreatment by similar appliances if necessary.

The rotating frame is a round table with a very flat convex conical surface; the ore for suspension flows on at one part of the centre and forms a thin deposit which is richest at the top and poorest at the bottom, and this deposit is washed off so as to form two classes by means of jets of water, under which the table passes as it turns round. Concave rotating tables, fed at the circumference, are also employed.

The percussion frame, the *Stossheerd* of the Germans, is a table suspended by four chains which receives a succession of blows from a cam in the direction of the stream flowing over it; after each blow it bumps against a piece of timber before receiving the next blow. These bumps cause the ore to settle, and after a thick deposit is formed it is dug off with the shovel, the upper end being richer than the middle or the tail.

Rittinger's side-blow percussion frame is a suspended rectangular table ABCD (fig. 101), receiving blows and bumps on the side and not on the end. A stream of orey water S is fed on at the corner A; clean water W is supplied by the other head-boards H, H, H; and the table is pushed out by cams in the direction of the arrow, and is driven back by a spring so that the cross-piece E strikes against a bumping-block K. The light particles travel down the table much faster than the heavy ones, and take a comparatively straight course; whereas the heavy and richer particles remain on the table, subject to the influence of the side-blows, for a much longer time, and travelling along a curved path reach the bottom at F. The middle class is discharged at G and the poor waste at K. The exact degree of richness of the products can be regulated by altering the pointers, strips of wood which can be turned so as to divide the stream of ore and waste where thought most desirable. The great advantage of this machine over the old percussion frame is its continuous action.

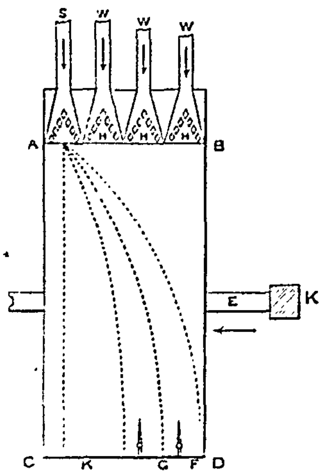


Fig. 101.

Frue vanner. The Frue vanner (fig. 102) may be looked upon as an improved form of Brunton's simple revolving belt. It is an endless band of india-rubber cloth, flanged on each side, which revolves slowly in the direction of the arrows, whilst at the same time it is shaken sideways by a crank motion. The orey water is fed on at A, clean water at B. The natural path of the particles is down the inclined belt, but the specifically heavier ones settle upon it and are carried upwards. Those that can resist the action of the stream of clean water at B go over the end and are washed off as the belt passes through the tank. The poor stuff falls into the waste launder. The degree of concentration can be regulated by the slope and speed of the belt and the strength of the streams of ore and water. The Frue vanner has the disadvantage that it makes only two classes, rich and poor, without any intermediate product.

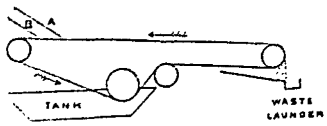


Fig. 102.

Buddles. The hand buddle is a rectangular wooden box with a sloping bottom. A stream of fine ore and waste suspended in water is fed in at the upper end and gradually forms a deposit on the bed of the buddle. A boy with a broom keeps the top of the sediment smooth, so as to ensure regularity of action. After a thick deposit has accumulated, it is dug out in sections which decrease in richness from the upper end (*head*) to the lower end (*tail*).

Round buddles, like rotating frames, are of two kinds, convex and concave. The convex round buddle (figs. 103[1] and 104) is a circular pit with a truncated cone, or head, of varying size in the centre, and a bottom sloping towards the circumference. The orey stream A falling over this head runs down gently, depositing the heaviest particles near the top, the lighter ones further down, whilst the lightest of all flow away at C. The surface of the sediment is kept even by revolving brushes D. This machine may be compared to a number of hand buddles arranged radially round a centre. The deposit that is formed is dug out in rings of varying richness.

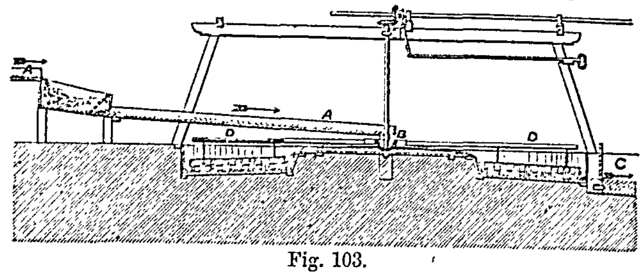


Fig. 103.

Scale.

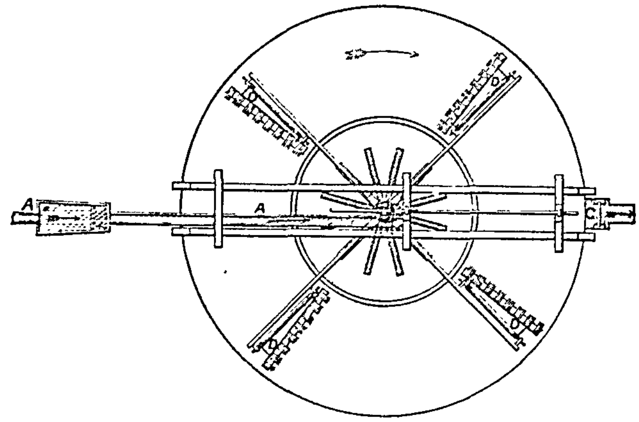


Fig. 104.

The concave buddle is a circular pit with the bottom sloping towards the centre. The stream of ore is fed all round the circumference, and runs inwards to the middle, where the lightest particles escape. The rich head is of course near the circumference.

Keeve. The keeve is a large tub in which the fine stuff is stirred with water and then is allowed to settle from a state of suspension while blows are being struck on the side of the tub. The deposit is afterwards scraped out in layers which increase in richness as they approach the bottom.

Dressing different ores. The series of processes employed in dressing an ore varies, not only according to the nature of the particular mineral to be concentrated, but also according to the size of its particles and the nature of the other minerals with which it is associated.

Gold. With gold the reduction in size is usually effected by stone-breakers and stamps, and much of the metal is then caught by mercury; what escapes is concentrated with its accompanying pyrites by inclined tables covered with blankets, or by buddles, and the concentrate is treated by amalgamation or chlorination. See GOLD, vol. x. p. 746.

Silver. In the case of silver the ore is frequently pulverized by stamps, and the resulting *pulp* amalgamated in pans or barrels. The ore may also be concentrated by any of the various machines described, and delivered to the smelter. Many of the ores of silver are sent to the smelting works without any concentration by water, as this would cause a serious loss.

Lead. Lead ore is generally crushed by rolls, often after a preliminary reduction in size by the stone-breaker. The crushed ore is classified by revolving screens down to the size of 1 mm., and the resulting grains concentrated by jigging; *dredge*, or grains of ore and matrix, must be recrushed, sized, and jigged. The finer sizes are classified by pyramidal boxes and concentrated by frames, rotating tables, and buddles.

Zinc. Zinc ore is dressed in the same way as lead ore; and, as galena and zinc-blende are frequently intimately associated together, it is necessary to separate them by the use of the jig, buddle, and frame.

[1] Henry T. Ferguson, "On the Mechanical Appliances Used for Dressing Tin and Copper Ores in Cornwall," *Proc. Inst. Mech. Eng.*, 1873 pl 41.

Tin. Tin-bearing rock is crushed by the stone-breaker and then stamped fine. The resulting sand and slime may be concentrated by the repeated use of the round buddle, with the keeve for a final cleaning; but often the sand only is enriched by the buddle, whilst the very finest particles, constituting an almost impalpable mud (*slime*) when mixed with water, are treated by frames. When much pyrites is present it is necessary to make a preliminary concentration and roast the enriched product (*witts*) in a furnace. The calcination converts the heavy iron and arsenical pyrites into a light oxide which can be got rid of with the rest of the waste by buddling and framing. The final product from the keeve is clean enough to approach pure cassiterite in the percentage of metal. Alluvial tin ore is concentrated in *sluice-boxes*, and sometimes by jiggers, after a preliminary treatment in a *puddling-machine* (GOLD, vol. x. p. 745) if there are balls of clay which have to be broken up. When the alluvial ore occurs as a hard conglomerate (*cement*), it has to be stamped.

Copper. Copper ores are treated by crushing by rolls and sometimes stamps, sizing by trommels, and then jigging and buddling; but, as some of the ores are very friable and easily carried away by water, hand-picking is employed to a greater extent than with lead and tin ore, and the enrichment by water is not carried so far on account of the inevitable loss that would ensue. The amount of concentration depends upon the distance from the smelting works, and the mine-owner has to calculate whether it is best to get a low price for a large quantity of ore, after paying the carriage, or a higher price for a smaller lot (*parcel*) when due allowance has been made for the cost of dressing and loss sustained in that process. Thus, for instance, in Cornwall, the ore containing copper pyrites is dressed so as to contain only from 5 to 8 or 9 per cent. of metal, because it can easily be conveyed to Swansea by sea, and because further reduction in bulk would cause greater loss in value than the saving of freight.

Loss in dressing. The loss in dressing is very considerable. P. von Rittinger estimates it at from 30 to 50 per cent., and stubborn facts bear out his conclusions. Heaps of refuse from dressing floors are frequently worked over again with profit; and in the year 1881 no less than 909 tons of "black tin" (*i.e.*, concentrated tin ore fit for the smelter), worth £35,283, were extracted from the muddy water allowed to flow away from the dressing floors of some of the principal Cornish tin mines.

The fall in air has been employed instead of the fall in water for concentrating purposes, and several ingenious air-jigs have been constructed and worked upon this principle.

Separation by magnetism. In exceptional cases magnetic attraction may be utilized. Magnetic iron can be separated in this way, and the magnetic process is applied for treating mixed blende and chalybite, the specific gravities of which are too close to render concentration by water practicable. The mixed ore is calcined, and the chalybite is thus converted into magnetic iron, which can be extracted by a magnetic separator, leaving saleable blende.

Recent improvements. Before concluding this part of the subject we will briefly enumerate the principal improvements that have been made in metal-mining during the last quarter of a century. They are as follows:—diamond-drill for prospecting; machine drills for driving, sinking, and stoping; use of compressed air for winding underground; stronger explosives, especially the nitro-glycerin compounds dynamite and blasting gelatin; increased use of steel for various purposes; Blake's stone-breaker and continuous jiggers; extended application of hydraulic mining; larger employment of electricity both for blasting purposes and for signalling by telegraph and telephone. It may be reasonably hoped that ere long electricity will render increased services to the miner for lighting the workings and for the transmission of power.

Recent British legislation. 14. *Recent Legislation affecting Mines in the United Kingdom.*[1]—In England the person owning the surface of a freehold is *prima facie* entitled to all the minerals underneath, excepting in the case of mines of gold and silver, which belong to the crown. The crown, however, does not claim gold and silver extracted from the ores of the baser metals. The ownership of the minerals can be, and often is, severed from that of the surface, the latter being sold whilst the mineral rights are reserved by the original owner. Local customs, now regulated by Acts of Parliament, are still in force in Derbyshire (High Peak Mining Customs and Mineral Courts Act, 1851, 14 & 15 Vict. c. 94, and the Derbyshire Mining Customs and Mineral Courts Act, 1852, 15 & 16 Vict. c. 43) and in the Forest of Dean (1 & 2 Vict. c. 43, and 24 & 25 Vict. c. 40). The Stannaries Act (32 & 33 Vict. c. 19) regulates the commercial dealings of mining companies in Cornwall and Devon, and provides for their liquidation.

The working of mines in the United Kingdom is controlled by five Acts of Parliament, viz., "The Coal Mines Regulation Act, 1872" (35 & 36 Vict. c. 76), "The Metalliferous Mines Regulation Acts, 1872 and 1877" (35 & 36 Vict. c. 77, and 38 & 39 Vict c. 39), "The Stratified Ironstone Mines (Gunpowder) Act, 1881" (44 & 45 Vict. c. 26), and "The Slate Mines (Gunpowder) Act, 1882" (45 Vict. c. 3). The last three Acts simply refer to the annual returns, and exemptions from certain restrictions concerning the use of gunpowder.

The Coal Mines Regulation Act applies to mines of coal, stratified ironstone, shale, and fire-clay. The Metalliferous Mines Regulation Act applies to all mines not included under the Coal Mines Act, and therefore controls not only workings for lead, tin, copper, and iron, commonly known as mines, but also the salt-mines, and underground quarries worked for stone, slate, or other earthy minerals. The principal provisions of the Coal Mines Regulation Act have been set forth at vol. vi. p. 78; those of the Metalliferous Mines Regulation Act are similar, but less strict owing to the almost complete absence of fire-damp. One important difference is that the manager of a mine under the Metalliferous Act need not hold any certificate of competency or service.

Other Acts of Parliament are the "Explosives Act, 1875" (38 Vict. c. 17), regulating the manner in which explosives are stored; the "Elementary Education Acts, 1876 and 1880" (38 & 39 Vict. c. 79, and 43 & 44 Vict. c. 23), regulating the employment of children; the "Factory and Workshop Act, 1878" (41 Vict. c. 16), which applies to the dressing floors of mines under the Metalliferous Mines Regulation Act.

The statute of Elizabeth (43 Eliz. c. 2) which was passed for raising money for the relief of the poor mentions coal mines, but omits other mines; these have been made subject to poor-rates by "The Rating Act, 1874" (37 & 38 Vict. c. 54). The "Employers' Liability Act, 1880" (43 & 44 Vict. c. 42), extends and regulates the liability of employers to make compensation for personal injuries suffered by workmen in their service. Finally, if, as sometimes happens, works are put up at a mine for roasting copper ores with common salt in order to extract the metal by the wet way, the provisions of the "Alkali, &c., Works Regulation Act, 1881" (44 & 45 Vict. c. 37), must be attended to.

It is thus very evident that the laws affecting mines have received most important additions during the last few years.

Accidents. 15. *Accidents in Mines.*—Mining is one of the occupations that may decidedly be called hazardous. This fact has been thoroughly impressed upon the public mind by explosions of fire-damp in collieries; but, though accidents of this kind are appalling, owing to the number of victims who perish at one time, fire-damp is by no means the worst enemy with which the miner has to contend. Falls of roof and sides both in collieries and metal mines are far more fatal in their results. With the risks attending the collier's calling we need not deal, as statistics upon

[1] For information concerning the laws relating to mines in the United Kingdom, see W. Bainbridge, *A Treatise on the Law of Mines and Minerals*, 1878, and Arundel Rogers, *The Law relating to Mines, Minerals, and Quarries in Great Britain and Ireland, with a Summary of the Laws of Foreign States*, 1876.

this subject have been already given (see COAL, vol. vi. p. 79); but the figures below relating to metalliferous mines prove that the occupation of the metal miner is very little less dangerous.

Mines classed under the Metalliferous Mines Regulation Act in Great Britain and Ireland.

	Persons Employed.			Number of Deaths from Accidents.						Death-rate from Accidents per 1000 persons employed.		
				Under Ground.				Above Ground.	General Total.			
	Under Ground.	Above Ground.	Total.	Falls of Ground.	In Shafts.	Miscellaneous.	Total.			Under Ground.	Above Ground.	Under Ground and Above Ground.
1874	34,036	22,325	56,361	40	34	15	89	14	103	2·61	0·62	1·82
1875	34,905	23,168	58,073	32	35	33	100	19	119	2·86	0·82	2·05
1876	34,109	23,388	57,497	25	16	23	64	6	70	1·87	0·25	1·21
1877	34,095	23,300	57,395	41	21	24	86	11	97	2·52	0·47	1·69
1878	30,624	20,834	51,458	27	19	23	69	8	77	2·25	0·38	1·49
1879	28,265	18,795	47,060	24	16	16	56	8	64	1·98	0·42	1·36
1880	32,045	20,863	52,908	31	21	19	71	13	84	2·21	0·62	1·59
1881	33,291	21,651	54,942	36	22	32	90	9	99	2·70	0·41	1·80
1882	33,814	21,692	55,506	30	27	17	74	18	92	2·18	0 83	1·65
Total and averages for the nine years	295,184	196,016	491,200	286	211	202	699	106	805	2·37	0·54	1·63

This table[1] shows that the average accidental mortality of the persons employed *underground* in metalliferous mines is 2·37 per 1000. During the ten years 1873–1882 the corresponding mortality at mines under the Coal Mines Act was 2·57, showing a difference of only 0·20 per 1000 in favour of the metal miner; and when we take the well-known metalliferous district of Cornwall and Devon we find a death-rate for the ten years mentioned of 2·63 per 1000, which therefore exceeds that of coal mines.

Reference to the table shows that more than one-third of the deaths were caused by falls of ground. The actual percentages of the deaths are as follows:—falls of ground 35·5, in shafts 26·2, miscellaneous 25·1, on surface 13·1. The accidents in shafts are due to falls from ladders, cages, and man-engines, ropes and chains breaking, overwinding, and other causes, whilst the miscellaneous accidents include numerous fatalities in connexion with blasting operations. The surface accidents are mostly caused by persons becoming entangled in machinery, and there have been several fatal boiler explosions.

In spite, however, of all the dangers to which miners are exposed, they are less likely to be the victims of accident than railway servants, among whom the rate of fatal accidents varies from 2·5 per 1000 on passenger traffic lines to 3·5 per 1000 on lines possessing a heavy goods traffic.[2]

Statistics concerning accidents in mines are published by many foreign countries; the most minute are those prepared by the Government mining engineers in Prussia. The average annual death-rates per 1000 persons employed below ground and above ground from accidents in mines in Prussia during the fifteen years 1867 to 1881 have been:—coal mines 2·952, lignite mines 2·474, metal mines 1·446, other mines 1·693, all the mines together 2·476. In making any comparison between these figures and those we have given for Great Britain, it is necessary to recollect that the mines under the Coal Mines Act include some workings which in Prussia would be classed as metalliferous, and that British mines under the Metalliferous Act include underground stone-quarries.

Before concluding the subject of accidents, it is necessary to point out that successful efforts have been made of late years to mitigate their results. In the first place, persons equipped with the Fleuss breathing apparatus can now enter mines after explosions, in spite of the noxious and irrespirable gases, and save lives which would otherwise be sacrificed.[3] Secondly, by means of the instruction afforded by classes established by the St John Ambulance Association, miners are learning how best to render first aid to the injured before the arrival of a medical man, and there is no doubt that many valuable lives have been lost in times past for want of this knowledge. Thirdly, a vast amount of good has been done by the establishment of Miners' Permanent Relief Societies in different districts, which afford aid to persons disabled by accidents and to the dependent relatives of those who have unfortunately lost their lives by any mining fatality.

16. *Useful Minerals produced in Various Parts of the Globe.*

Great Britain and Ireland.—The mineral produce of the United Kingdom for the year 1881 is summed by Mr Robert Hunt[4] as follows:—

[1] From *Reports of H.M. Inspectors of Mines for the year* 1882, p. xxxvi.

[2] *The Rate of Fatal and Non-Fatal Accidents in and about Mines and on Railways, with the Cost of Insurance against such Accidents*, by Francis G. P. Neison, London, 1880.

[3] *Reports of H. M. Inspectors of Mines for the year* 1881, Mr Bell's Report, p. 463.

[4] *Mineral Statistics of the United Kingdom* for 1881, p. ix.

Minerals.	Quantities.		Values.		
	Tons	cwts.	£	s.	d.
Coal	154,184,300	0	65,528,327	10	0
Iron ore	17,446,065	6	6,201,068	6	6
Tin ore	12,898	3	697,444	5	3
Copper ore	52,556	1	190,057	8	7
Lead ore	64,702	5	656,725	0	0
Zinc ore	35,527	7	110,043	10	8
Iron pyrites	43,616	14	30,033	6	5
Gold ore		1½	18	0	0
Silver ore	5	19	358	7	0
Cobalt and nickel ore	63	14	309	12	8
Manganese	2,884	0	6,441	5	0
Wolfram	54	7	544	1	9
Ochre and umber	7,996	9	12,286	7	0
Arsenic	6,156	8	45,070	7	6
Fluor spar, &c.	372	14	253	10	0
Clays	2,401,421	0	1,200,210	0	0
Salt	2,298,220	0	1,149,110	0	0
Barytes	21,313	11	23,894	3	10
Sundry minerals, including coprolites, gypsum, calcspar, shales, &c.	...		349,500	0	0

The total value of minerals produced in 1881 was £76,201,695, 2s., exclusive of slate, building-stone, limestone, and other stones worked by mines and quarries.

The quantity of coal raised in 1882 was 156,499,977 tons.

The metals obtained from the ores produced in the United Kingdom in 1881 were—

Metals.		Quantities.	Values.
			£
Gold	ounces	4½	18
Silver, from ore	"	1,650	360
Silver, from lead	"	308,398	67,140
Pig iron	tons	8,144,449	20,361,122
Tin	"	8,615	839,680
Copper	"	3,875	263,500
Lead	"	48,567	728,805
Zinc	"	14,947	252,608
Other metals, estimated		...	1,275
Total value of metals produced in 1881		...	£22,514,508

The total value of minerals and metals obtained from the mines and other mineral workings of the United Kingdom in 1881 was—

	£
Coal	65,528,327
Metals, as above	22,514,508
Minerals, not reduced—salt, clays, &c.	2,817,652
	£90,860,487

From these tables it is evident that coal and iron are by far the most important mineral productions of the United Kingdom, as 94 per cent. of the total value is due to these two substances.

France.—The mineral productions of France[5] for the year 1880 are set forth in the following table:—

	Quantities.	Values.
	Metric Tons.	Francs.
Mineral fuel	19,362,000	246,687,000
Peat	248,000	2,755,000
Asphalt rock and bituminous shale	144,000	1,023,000
Iron ore	2,874,000	14,909,000
Iron pyrites and sulphur	133,000	2,114,000
Metallic ores	53,000	4,690,000
Rock-salt	333,000	11,814,000
Bay-salt	367,000	6,719,000
General totals	23,514,000	290,711,000

[5] *Statistique de l'Industrie Minérale et des Appareils à Vapeur en France et en Algérie*, Année 1880, Paris, 1882, p. 45.

The quantities of metal produced in France from native and foreign ores in 1880[1] were—

Pig iron	1,725,000 metric tons.	Nickel	30 metric tons.
Lead	6,500 ,, ,,	Gold	31 kilogrammes
Copper	3,400 ,, ,,	Silver	40,400 ,,
Zinc	16,200 ,, ,,	Aluminium	1,150 ,,

Germany.—The mining industry of the German empire is of high importance. The output of the mines in 1881 is shown by the following table,—taken from the *Stat. Jahrb. für das Deutsche Reich*, Berlin, 1883, p. 27. The production of common salt, potassium chloride, and other salts from brine is also considerable. The total quantity for the German empire in 1881 was 693,000 metric tons, worth 33,567,000 marks, including 113,200 tons of potassium chloride valued at 14,090,000 marks.

	Coal.	Lignite.	Rock-Salt.	Potash Salts.	Iron Ore.	Zinc Ore.	Lead Ore.	Copper Ore.	Silver and Gold Ore.	Iron Pyrites and other Vitriol and Alum Ores.	Other Mining Products.	Total Value of all the Mining Products.
	Unit 1000 Metric Tons.	Unit 1000 Metric Tons.	Unit 1000 Metric Tons.	Unit 1000 Metric Tons.	Unit 1000 Metric Tons.	Unit 1000 Metric Tons.	Unit 1000 Metric Tons.	Unit 1000 Metric Tons.	Unit 1000 Metric Tons.	Unit 1000 Metric Tons.	Unit 1000 Metric Tons.	Unit 1000 Marks.
Prussia[2]	43780·5	10412·2	207·8	545·4	3906·3	659·2	159·7	523·6	0·1	142·0	33·2	326,423
Bavaria	519·8	18·1	0·9	...	75·6	...	0·8	0·0[3]	...	1·1	1·5	5,124
Saxony[4]	3707·8	600·7	...	...	23·8	...	1·7	0·1	26·7	0·1	1·2	33,057
Würtemberg	...	...	84·2	...	19·3	...	...	...	...	0·1	...	752
Baden	9·4	...	...	...	...	0·3	...	...	...	...	0·0[3]	110
Hesse	...	30·7	...	...	133·8	...	...	...	...	...	0·6	1,115
Mecklenburg	...	12·3	...	...	...	...	...	...	...	...	...	46
Thuringia	0·9	735·3	...	...	28·4	...	...	0·0[3]	...	0·4	1·4	1,626
Brunswick	...	273·7	...	...	96·4	...	0·9	...	...	...	18·0	1,578
Anhalt	...	766·1	19·0	360·5	...	...	1·4	...	...	...	2·1	6,344
Schaumburg-Lippe	108·9	...	...	...	...	...	...	...	...	...	...	965
Waldeck	...	...	...	...	32·3	...	...	...	...	...	0·0[3]	170
Alsace-Lorraine	560·9	3·2	...	...	1096·0	...	0·3	...	...	2·4	9·7	6,690
German empire	48688·2	12852·3	311·9	905·9	5411·9	659·5	164·8	523·7	26·8	146·1	67·7	384,000
Luxemburg	...	...	...	...	2161·9	...	...	...	...	...	...	4,994
Together	48688·2	12852·3	311·9	905·9	7573·8	659·5	164·8	523·7	26·8	146·1	67·7	388,994

Austria-Hungary.—Among the famous mines of the Austria-Hungarian empire may be mentioned those of Hungary and Transylvania for gold and silver; Styria produces much of the iron; quicksilver is yielded by the mines of Idria in Carniola, lead and silver by those of Przibram in Bohemia; salt is obtained in the Austrian Alps and in Galicia, which also produces petroleum and ozokerite.

The production of minerals and metals in Austria[5] during the year 1881 was as follows:—

Gold ore	784 metric tons	—Metallic gold	18·6	kilogrammes.
Silver ore	12,383 ,, ,,	— ,, silver	31,359	,,
Quicksilver ore	48,204 ,, ,,	— ,, mercury	398	metric tons.
Copper ore	4,445 ,, ,,	— ,, copper	481	,, ,,
Iron ore	618,963 ,, ,,	— ,, iron	379,639	,, ,,
Lead ore	13,542 ,, ,,	— ,, lead	6,385	,, ,,
		Litharge	2,996	,, ,,
Zinc ore	27 339 ,, ,,	—Metallic zinc	4,119	,, ,,
Manganese ore	9,109 ,, ,,			
Graphite	13.379 ,, ,,			
Petroleum	1,249 ,, ,,			
Lignite	8,961,498 ,, ,,			
Coal	6,343,315 ,, ,,			

Exclusive of salt, the value of the produce of the Austrian mines in 1881 was 44,693,692 florins. The total output of salt in 1881 was 267,279 metric tons, valued according to the monopoly prices at 23,000,498 florins.

Hungary in 1879[6] produced

Gold	1,593 kilogrammes.	Iron	118,321 metric tons.
Silver	18,660 ,,	Coal	674,008 ,, ,,
Copper	1,035 metric tons.	Lignite	932,475 ,, ,,
Lead	1,967 ,, ,,	Iron pyrites	56,282 ,, ,,
Mercury	22 ,, ,,		

Belgium.—Belgium is rich in coal, the output in 1881 being no less than 16,873,951 metric tons, valued at 163,704,242 francs. Though it produces iron ores, it is largely dependent upon other countries, and especially the grand-duchy of Luxemburg, for supplies for its blast furnaces. The principal lead mine is that of Bleiberg, and the calamine deposits in the neutral territory of Moresnet have long been worked with success by the celebrated Vieille Montagne Company, which also owns zinc mines in Belgium, Germany, Sweden, Sardinia, and Algeria.

Russia.—In a vast empire like Russia it is not surprising that there should be valuable deposits of a great variety of minerals. Among the most important are the auriferous alluvia of the Ural mountains and Siberia, which in 1880 yielded 115,940 troy ℔ of gold, worth more than 5 millions sterling. Platinum is found associated with the gold-bearing sands of the Urals; the output in 1880 was 7895 troy ℔. Zinc ore is largely worked in Poland. Important supplies of chromic iron ore are derived from the Urals, amounting in 1880 to more than 8000 tons. The metallic copper produced in 1880 was about 3100 tons, and the oil wells of Baku yielded in that year 346,000 tons of petroleum. Russia also possesses mines of iron ore, manganese, lead, silver, coal, and lignite. A little tin ore is furnished by Finland.

Italy.—The most important mineral in Italy[7] is sulphur, 359,540 tons (metric), worth 36,448,453 lire, having been obtained in 1880, and mainly from seams containing the native element in the Miocene rocks of Sicily and Romagna.

The celebrated iron mines of the island of Elba have been worked from very early times, and furnish a valuable ore; and the deposits of calamine, lead ore, and silver ore in Sardinia form no small proportion of the mineral wealth of the Italian kingdom. The gold mines in and near the Val Anzasca (Piedmont) are producing more than 7000 ounces of metal yearly.

Spain.—Spain is justly celebrated for its mineral wealth. It produces more cupreous pyrites than any other country in the world, and very large amounts of lead ore and quicksilver; and its iron ores are abundant and of excellent quality. The principal lead mines are in the provinces of Jaen (Andalusia) and Murcia, and the total amount of metallic lead produced in Spain or from Spanish ores is estimated to be 120,000 tons yearly.

Cinnabar, the heavy red ore of mercury, naturally attracted attention at a very early date, and the world-renowned Almaden mine has been worked from time immemorial. The output in 1880 was 1387½ tons (metric) of quicksilver.[8]

The cupreous pyrites, often known as sulphur ore, is obtained from the province of Huelva, where vast deposits occur over a belt of country nearly 100 miles long by 20 miles wide. The Rio Tinto mines are the largest in the district, and are worked on a gigantic scale. The company employs upwards of 10,000 hands, or more persons than are engaged in all the Cleveland iron mines, and the output is upwards of a million tons per annum. About one-quarter of this, containing 3½ per cent. of copper, is exported, mainly for the manufacture of sulphuric acid and subsequent treatment for copper and silver, whilst the remaining three-quarters, with 2¼ to 2½ per cent. of copper, are treated on the spot. The ore contains rather less than 1 oz. of silver to the ton, and a few grains of gold. These are profitably extracted from the burnt ore by Claudet's process, and some idea of the importance of the copper and silver will be gained by reference to the following figures.[9] During the year 1881 there were obtained from cupreous pyrites imported into the United Kingdom in 1881, mainly from Spain and Portugal, 14,000 tons of copper, 258,463 oz. of silver, and 1490 oz. of gold. The total value of the silver and gold was £64,195.

The total output of iron ore in 1880 was 3,565,338 metric tons,[10] more than two-thirds, viz., 2,683,627 tons, being obtained from the celebrated mines near Bilbao in the province of Biscay. England, France, Belgium, and Germany are all glad to draw supplies of

1 *Statistique de l'Industrie Minérale et des Appareils à Vapeur en France et en Algérie*, Année 1880, Paris, 1882, pp. 59 and 72.

2 Detailed statistics concerning the mineral produce of Prussia are given every year in the *Zeitschrift für das Berg-, Hütten-, und Salinen-Wesen im Preussischen Staate* (Berlin).

3 Quantity less than 50 tons.

4 Detailed statistics of the mineral produce of Saxony are given yearly in the *Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen* (Freiberg).

5 *Stat. Jahrb. des k. k. Ackerbau-Ministeriums für* 1881, Heft iii., Lief. 1, Vienna, 1882.

6 "Der Bergwerksbetrieb Ungarns im Jahre 1879," *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1881, p. 271.

7 *Notizie statistiche sulla Industria Mineraria in Italia dal* 1860 *al* 1880, Rome, 1881, p. 406.

8 *Estadistica Minera de España, correspondiente al año de* 1880, Madrid, 1882, p. 37.

9 Hunt, *Mineral Statistics*, &c., p. 45.

10 *Estadistica Minera*, &c., *ut supra*, p. 15.

excellent red and brown hæmatite from the Bilbao mines. Murcia comes next in importance to Biscay, with a production of 539,328 tons.

Portugal.—The great mineral belt of Huelva extends into Portugal, and deposits of cupreous pyrites almost identical with that of Rio Tinto have been wrought from very early ages. The principal mine, San Domingos, is close to the Spanish frontier. It is estimated that the workings had yielded up to the year 1877 no less than 3,578,745 English tons of cupreous pyrites, by far the greater part of this having been extracted in recent times. The quantity of ore raised from the mine in 1882 was 405,029 tons.

Portugal possesses notable manganese mines, but produces comparatively small quantities of iron, lead, and copper.

Norway.—The mines at Kongsberg are famous for the large quantities of native silver they produce, and enormous masses are sometimes met with. The annual output is from 10,000 to 12,000 troy ounces. Copper ore and cupreous pyrites are also mined in Norway, and there are important workings for nickel and cobalt and for apatite. Alluvial gravels have been washed for gold in Norwegian Finland.

Sweden.—The most important mineral obtained in Sweden is iron ore, much being in the form of magnetite; red hæmatite also is mined, and brown hæmatite is dredged up from some of the lakes. The principal iron-producing districts are those of Norberg, Dannemora, Nora, and Perseberg. The output of the Swedish mines in 1880 was—

Iron ore	775,205 tons.	Zinc ore	43,452 tons.
Lead ore	12,958 „	Copper ore	29,380 „

Greece.—One of the most interesting undertakings of modern times has been the re-working of the Laurium mines, which are situated in the southern extremity of Attica; and an account of them written by Cordella furnishes many curious details concerning the methods of mining, washing, and smelting employed by the ancients. The workings for lead and silver appear to have been carried on with the greatest vigour between 600 B.C. and the Peloponnesian War, and were finally abandoned in the 1st century of the Christian era. Huge piles of slag which had accumulated from the old smelting works were found to be well worth being re-worked for silver and lead, and operations were commenced in 1864. Five years later the old heaps of mine refuse began to be treated, and at last in 1875 a French company resumed working the mine. A Greek company employing some 3000 persons is now producing annually from the old mine heaps no less than 8000 to 9000 tons of pig lead, yielding 45 oz. of silver to the ton, whilst the mines of the *Compagnie française des mines du Laurium* made an output in 1881 of 36,664 tons (metric) of roasted calamine, with 40 to 60 per cent. of zinc, in addition to lead ore and mixed ores. Cordella calculates that during the three hundred years the Laurium mines were worked by the ancients the total amount of lead produced was 2,100,000 tons, with 22½ million troy lb of silver. Besides this the ancients left behind two million tons of lead slags containing on an average 10·67 per cent. of lead, 109 million tons of mine refuse with 1½ to 18 per cent. of lead, and excavations to the extent of 51 million cubic yards with lead ore still in sight. They did not touch the calamine deposits.[1] Next in importance to lead, silver, and zinc comes bay-salt, and after that emery. The island of Naxos furnished 3300 metric tons of emery in 1877, valued at £28,000.

Africa.—Algeria is rich in iron, and three-fourths of the value of its total mineral output are due to ores of this metal. In 1880 the iron mines produced 614,000 metric tons of ore, Mokta-el-hadid mine, near Bona, alone yielding about 300,000 tons. Algeria also possesses mines of copper, lead, zinc, and antimony.

The name "Gold Coast" applied to part of the shores of Africa, denotes its productiveness of the precious metal, and it is probable that very important supplies of gold will one day be derived from various districts of the Dark Continent.

Cape Colony possesses rich copper mines in the Namaqualand division, which in 1882 produced ore and metal worth £331,546; however, the most valuable and remarkable mineral deposits of Africa at the present time are the diamond mines. The first diamonds were obtained from recent gravel in the bed of the Vaal river, and it was afterwards discovered that the precious stones could be obtained from the so-called dry diggings. The most important of these, the Colesberg Kopje, now known as the Kimberley mine, produced in 1881 diamonds weighing 900,000 carats, worth £1,575,000. Three other neighbouring mines are Old De Beer's, which yielded 300,000 carats in 1881, worth £600,000, Du Toit's Pan, and Bulfontein. The value of the diamonds raised in South Africa since 1870 amounts to forty millions sterling;[2] indeed the Kimberley mine alone was estimated in 1877 to have already produced ten million pounds worth of diamonds, extracted from 4 million tons of diamantiferous rock.

Asia.—For many centuries India was regarded as possessing fabulous mineral wealth, and a strong basis for this idea may be found in the existence of traces of mining on a very extensive scale. No doubt in early days India did supply what then appeared to be very large quantities of metals, and a country that produces gold and precious stones is apt to be endowed by the popular mind with boundless riches. The actual amounts of mineral raised in India at the present day are comparatively small. Gold exists over considerable areas, but it remains to be proved that the gold mines of the Wynaad and Mysore can be profitably worked by British companies. Diamonds occur and are worked in alluvial diggings and in a conglomerate belonging to the Vindhyan formation. Sapphires and rubies are obtained from Upper Burmah. Ceylon[3] produced in 1880 no less than 10,286 tons of graphite or plumbago, valued at £192,879. Petroleum is abundant in Upper Burmah, and oil from wells has been utilized for upwards of twenty centuries. The total output in 1873 was estimated to be about 10,000 tons yearly. Tin ore occurs and is worked in Tenasserim. Passing into Siam and the Malay Peninsula we find deposits of alluvial tin ore, producing what is known in commerce as Straits tin. A little to the east are the islands of Banca and Billiton, which for many years have been a source of wealth to the Dutch Government. The sales of Banca tin in 1881 amounted to 4339 tons, and those of Billiton tin to 4735 tons, whilst 11,475 tons of Straits tin were exported from Penang and Singapore.[4] Stanniferous alluvia are also worked in Karimon, Singkep, and Sumatra, whilst the latter island possesses also valuable seams of coal.

Borneo furnishes coal, antimony ore, and some cinnabar; and river-gravels are washed for diamonds, gold, and platinum.

There is no doubt that the mineral wealth of China is enormous. In addition to important coal-fields it possesses numerous metallic mines. The province of Yunnan in the south of the empire seems to be specially favoured with regard to metalliferous wealth, for mines of gold, silver, copper, lead, tin, and iron are worked there, whilst jade and precious stones are found in the beds of rivers.

Japan produces more than 3000 tons of copper yearly, or about as much as the British Isles. The output of lead and tin is insignificant, but the quantity of silver, exceeding 300,000 oz. yearly, is worthy of notice. Gold, iron, and petroleum are other products of Japan.

The gold of Siberia has been mentioned in speaking of Russia.

Canada.—The Dominion of Canada is rich in minerals. Gold-bearing quartz veins are worked in Nova Scotia, whilst in British Columbia alluvial deposits are the main source of the supply. Silver occurs on Lake Superior, the most important mine being that of Silver Islet, which from 1869 to the spring of 1877 yielded 2½ million ounces of silver, and gave a profit of £200,000.

Rocks resembling the copper-bearing strata of the United States territory are mined in Michipoten island in Lake Superior. Iron ores, in the form of magnetite, red hæmatite, limonite, and ilmenite, are worked in various parts of Canada.

Petroleum is derived from oil wells in Western Ontario, and the quantity refined in 1875 was about 210,000 barrels, each of 40 gallons. It is in Ontario also that the veins of apatite exist from which a large amount of that useful mineral has been raised.

United States.—The mineral wealth of the United States is admirably summed up by Mr Richard P. Rothwell in his address to the American Institute of Mining Engineers.[5]

"*Production of Coal, Metal, and Petroleum in* 1881.[6]

Anthracite	30,261,940 tons (of 2240 lb).
Bituminous coal	42,417,764 „ (of 2000 lb).
Pig iron	4,144,000 „ (of 2240 lb).
Lead	105,000 „
Copper	31,000 „ „
Quicksilver	59,000 flasks (of 76½ lb. avoir
Gold	$31,870,000 (=1,541,711 oz.).
Silver	$45,078,000 (=34,865,960 oz.).
Petroleum	27,264,000 barrels (of 42 gallons).

"The statistics of other useful minerals and metals show an equally marvellous advance during the past thirty years. The production of pig iron, which in 1852 was 541,000 net tons, in 1861 was 653,000 tons, and in 1871 was 1,708,000 tons. Ten years later, in 1881, we produced no less than 4,144,000 tons, an increase in thirty years of nearly 800 per cent.

"Lead, which appears at 14,400 tons in 1852, varied but little from that figure until the construction of railroads into the argentiferous lead-mining districts of the west about 1870. Eureka, Nevada, Utah, and more recently Colorado, with its Leadville bonanzas. rapidly raised the production from 18,000 tons in 1871 to 47,000 tons in 1873, 75,000 tons in 1877, and 105,000 tons in 1881.

"Our production of copper steadily increased from 1000 tons in 1852 to 31,000 tons in 1881,—the enormous output of that unrivalled mine Calumet and Hecla steadying the production and neutralizing the fluctuations of the lesser mines.

"Quicksilver has shown wide fluctuations, due more to trade combinations than to the condition of the mines. In 1852 the output amounted to 20,000 flasks;

1 A. Cordella, "Mineralogisch-geologische Reiseskizzen aus Griechenland," *Berg- und hüttenmännische Zeitung*, vol. xlii., 1883, p. 21.

2 A. J. Macdonald, "The Value of the Cape as a Dependency of Great Britain," *The Times*, 3d May 1883.

3 *Statistical Abstract for the Several Colonial and other Possessions of the United Kingdom in each year from* 1860 *to* 1880, London, 1882, p. 39.

4 Hunt, *Min. Stat.* for 1881, p. 9.

5 *Engineering and Mining Journal*, vol. xxxiv. p. 174.

6 The total production of coal in the United States in 1882 amounted to 86,862,614 tons of 2240 lb (*Colliery Guardian* for 1883, p. 731). The quantities of metals produced in 1882 are estimated to be—pig iron 4,623,323 gross tons of 2240 lb each, lead 123,000 gross tons, copper 40,000 gross tons (*The Iron, Steel, and Allied Trades in* 1882, p. 188; *Eng. and Min. Jour.*, vol. xxxv. p. 27).

but it went as low as 10,000 flasks in 1860, and rose to 53,000 flasks five years later; from this it declined to 15,000 flasks in 1875, though in the following year it grew to 75,000 flasks. Last year we produced 59,000 flasks.

"Gold is the only metal in which our production has been declining. In 1852 it amounted to $60,000,000; but, with some fluctuations, it has now declined to less than $32,000,000 annually.

"The production of silver, on the contrary, has largely increased. Commencing in 1859 with $100,000, it has now attained $45,000,000. In 1877 only were these figures exceeded, and then only by about $1,000,000.

"The production of petroleum, that great American industry, has grown with wonderful rapidity. In 1859 it commenced with only 3000 barrels, and, after an almost uniform increase, it attained last year the enormous figures of 27,000,000 barrels. Scientific investigation has recently raised a note of warning in this industry, asserting the limited area of oil-producing territory and its approaching exhaustion."

Some valuable statistics concerning the production of the precious metals in the United States are contained in a report issued by the Census Bureau.[1] The output for the year ended 31st May 1880 is summed up as follows :—

	Gold.		Silver.		Total.
	Ounces.	Value.	Ounces.	Value.	Value.
Deep mines....	1,033,974	$21,374,152	31,717,297	$41,007,296	$62,381,418
Placers..........	580,767	12,005,511	80,177	103,661	12,109,172
All mines.......	1,614,741	33,379,663	31,797,474	41,110,957	74,490,620

The State producing the greatest value is Colorado, viz., $19,249,172, or gold 130,607 oz. and silver 12,800,119 oz. ; California comes next, having produced $18,301,828 of bullion, and then Nevada, with $17,318,909 of bullion.

The greatest gold producer among the States and Territories is California, with 829,676 oz. of gold, half from deep mines and half from placers. Next follows Nevada, with 236,468 oz. of gold, of which only about 1 per cent. came from placer mines ; then Dakota, 159,920 oz. of gold, nearly entirely produced by deep mines ; and in the fourth rank Colorado, 130,607 oz., with a placer production of less than 5000 oz.

The greatest silver producer is Colorado, with 12,800,119 oz.; then Nevada, 9,614,561 oz.; then Utah, 3,668,365 oz.; Montana, 2,246,938 oz. ; and fifthly Arizona, 1,798,920 oz.

It is useless within the limits of this article to attempt to convey an adequate idea of the enormous mineral resources of the United States. We can merely very briefly allude to some of the principal deposits, which are of commercial value on account of their magnitude, of scientific interest owing to their mode of occurrence, and of technical importance as having led to the introduction of considerable improvements in the arts of mining, milling, and dressing.

Among these may be mentioned the coal and anthracite mines and oil wells of Pennsylvania, the gold and quicksilver mines of California, the silver mines of Nevada, the lead and silver mines of Colorado, and the copper mines of Lake Superior. The articles COAL (vol. vi. p. 60) and GOLD (vol. x. p. 743) may be referred to for information concerning the occurrence of these minerals and the method of extracting gold by hydraulic mining and improved stamping machinery.

Quicksilver in the form of native mercury and cinnabar occurs in considerable abundance in California, and much of it is found in connexion with serpentine, either in the serpentine itself or in sandstone near its junction with serpentine. The most important mines are those of New Almaden in the southern part of the State near San Jose. The deposit at Sulphur Bank in Lake County is of much geological interest. It consists of native sulphur, gypsum, and cinnabar in a decomposed andesitic lava close to an extinct geyser from which boiling water still issues. The top of the bank was worked open-cast for sulphur, and then for sulphur and cinnabar, and now underground mining is carried on in stratified sandstone and shale impregnated with cinnabar and underlying the lava.

Some of the most marvellous silver mines in the world are those upon the Comstock lode in Nevada. A horizontal section of part of this great vein is shown on Plate IV., copied from the excellent and well-known report of Mr J. D. Hague.[2] The strike is nearly north and south, and the dip about 43° to the east. "The vein matter of the Comstock consists of crushed and decomposed country rock, clay, and quartz." "Up to January 1, 1880, the Comstock had yielded in twenty years about $325,000,000 worth of bullion. The total length of shafts and galleries is about 250 miles. The number of men employed in the mines in January 1880 was 2800, earning average wages of $4 a day. At the same date 340 men were at work in the amalgamating mills."[3] The heat of the Comstock lode is remarkable. On the 2700 feet level of the Yellow Jacket mine Mr Becker found the temperature of the water to be 153°, that of the air 126° ; whilst the water in the Yellow Jacket shaft at a depth of 3065 feet has a temperature of 170° Fahr.[4]

During the last few years the Comstock lode has been falling off in productiveness. In 1876 the total yield of the Comstock lode was $38,572,984 (gold, $18,002,906; silver, $20,570,078). During the census year ending May 31, 1880, the product of the whole Comstock district, including outlying veins, was $6,922,330 (gold, $3,109,156; silver, $3,813,174), showing a decline of $31,650,654, or 82·06 per cent., since 1876.[5]

Though the extraction of silver from its ores may be regarded as the business of the metallurgist rather than of the miner, we must not forget to mention that it is to the necessities of the treatment of the Nevada ores that we owe the system of pan amalgamation first developed in that State and practised since in Colorado.

Another district in Nevada which cannot be passed over in silence is that which contains the Eureka and Richmond mines, which are celebrated, not only for the silver they have produced, but also for the important trial in which the issue hinged upon the definition of the term vein or lode (p. 441). The bullion produced in the Eureka district from ore raised and treated during the census year ended May 31, 1880, was—gold, 62,893 oz.; and silver, 2,037,666 oz.; worth altogether $3,934,621.[6]

The history of Leadville in Colorado seems like a romance when we read of the rapid development of the mines, the creation of a large and important town, the erection of smelting works and the building of railways, under very adverse conditions, in the heart of the Rocky Mountains, all within the space of four or five years. It affords additional proof that the miner is the true pioneer of civilization. The main facts concerning the Leadville deposits are admirably summed up by Mr S. F. Emmons, from whose report[7] we borrow, not only the following facts, but also the geological section across the district (Plate IV.).

The principal deposits of the region are found at or near the junction of the porphyry with the Blue limestone, which is the lowest member of the Carboniferous formation. This bed is about 150 or 200 feet thick, and consists of dark blue dolomitic limestone. At the top there are concretions of black chert. The porphyry occurs in intrusive sheets which generally follow the bedding, and almost invariably a white porphyry is found overlying the Blue limestone. This porphyry is of Secondary age ; it is a white homogeneous-looking rock, composed of quartz and felspar of even granular texture, in which the porphyritic ingredients, which are accidental rather than essential, are small rectangular crystals of white felspar, occasional double pyramids of quartz, and fresh hexagonal plates of biotite or black mica. Along the plane of contact with the porphyry the limestone has been transformed, by a process of gradual replacement, into a vein consisting of argentiferous galena, cerussite, and cerargyrite mixed with the hydrous oxides of iron and manganese, chert, granular cavernous quartz, clay, heavy spar, and "Chinese talc," a silicate and sulphate of alumina. The vein seems to have been formed by aqueous solutions, which took up their contents from the neighbouring eruptive rocks and brought about the alteration of the limestone as they percolated downwards through it. In Carbonate Hill, a gradual passage may be observed from dolomite into earthy oxides of iron and manganese. The masses of workable ore are extremely irregular in shape, size, and distribution. They are often 30 to 40 feet thick vertically, and occasionally 80 feet, but only over a small area. The rich ore bodies are commonest in the upper part of the ore-bearing stratum. At Fryer Hill the Blue limestone is almost entirely replaced by vein material.

In the census year ended May 31, 1880, Lake County, Colorado, which includes the Leadville district, produced 28,226 gross tons of lead, with 3830 oz. of gold and 8,853,946 oz. of silver, of a total value of $13,032,464.[8]

The most important copper mines of the United States are those on Lake Superior, where the native metal occurs "in veins, in large masses, or scattered more or less uniformly in certain beds which are either amygdaloid or conglomerates."[9] The principal copper-producing districts are in Michigan, where the Portage Lake district, in Houghton county, contains the famous Calumet and Hecla mine, which alone produced 15,837 tons of copper in 1880, or about half the entire output of the United States. The deposit from whence this vast amount of copper was obtained is a bed of conglomerate, generally called a vein, dipping about 38° north-west. It has been worked for a depth of 2250 feet on the incline. In 1875 the stuff stamped yielded 4½ per cent. of copper.

In conclusion, we will point out that the value of the mining industry in the United States exceeds that of any other country in the world, Mr Porter estimating it for 1879–1880 at 360 million dollars, and that of Great Britain at 325 millions.[10] Germany holds

[1] Clarence King, special agent of the Census, *Statistics of the Production of the Precious Metals in the United States*, Washington, 1881, p. 69.

[2] *United States Geological Exploration of the Fortieth Parallel*, vol. iii., Mining Industry, Atlas, plate 11.

[3] Clarence King, *First Annual Report of the U.S. Geological Survey*, p. 39.

[4] *Op. cit.*, pp. 44, 45.

[5] Clarence King, *Statistics of the Production of the Precious Metals in the United States*, Washington, 1881, p. 19.

[6] *Op. cit.*, p. 21.

[7] *Abstract of a Report upon the Geology and Mining Industry of Leadville, Colorado*, Washington, 1882.

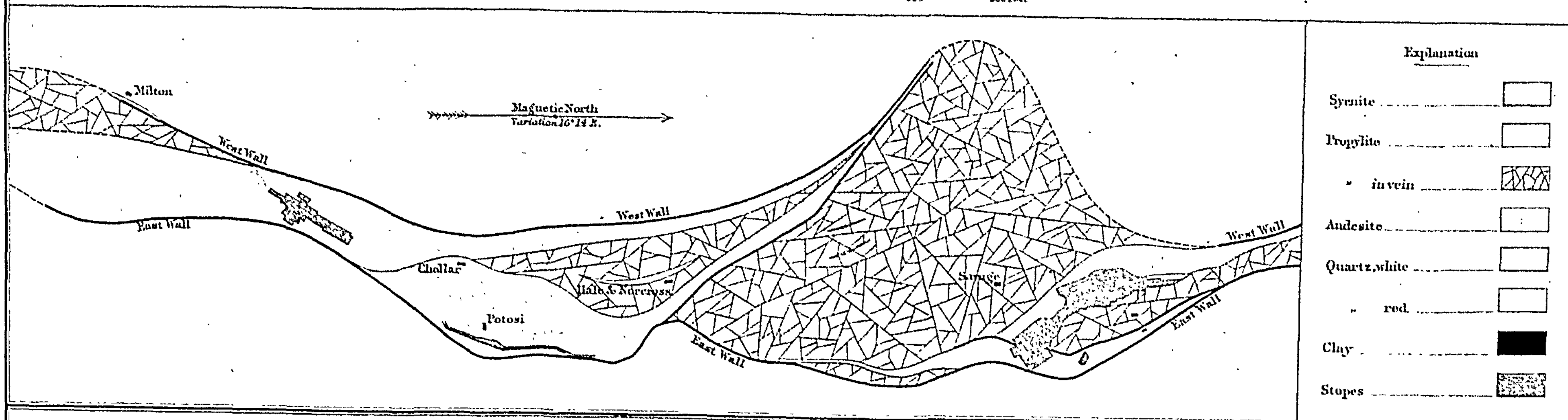
[8] Clarence King, *op. cit.*, p. 47.

[9] Charles E. Wright, commissioner, *Annual Report of the Commissioner of Mineral Statistics for the State of Michigan for* 1880, Lensing, Michigan, 1881.

[10] Robert P. Porter, *The West from the Census of* 1880, Chicago and London, 1882, p. 19.

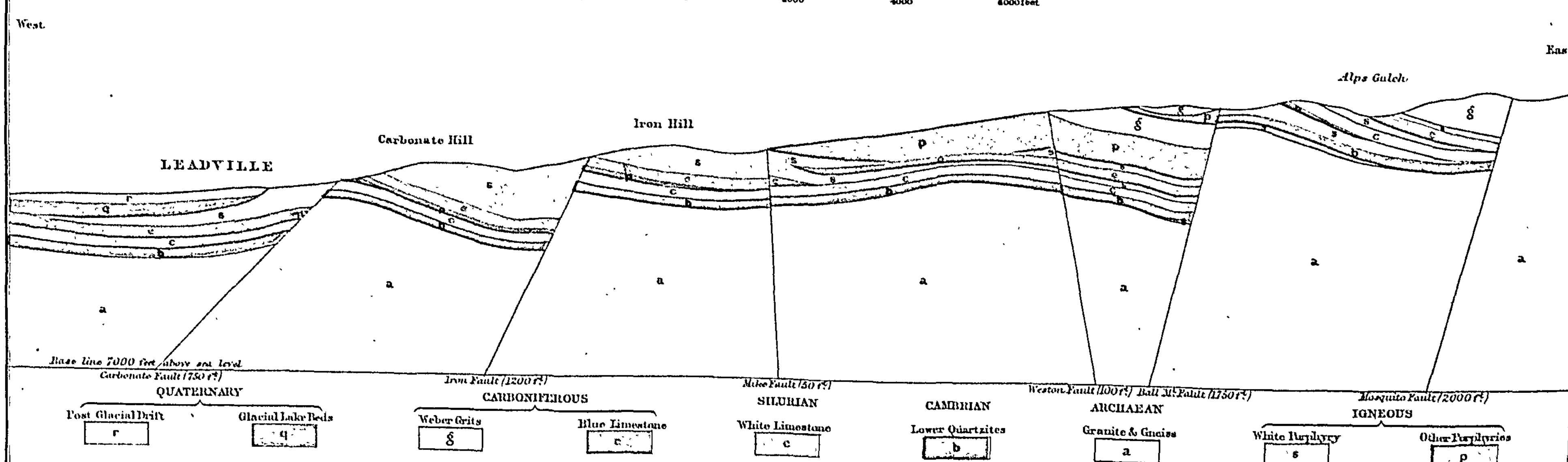
HORIZONTAL SECTION OF PART OF THE COMSTOCK LODE, 331 FEET BELOW THE OUTCROP AT ...

Scale: 400 feet to 1 inch



EAST AND WEST SECTION ACROSS PART OF THE LEADVILLE MINING DISTRICT.

Horizontal & Vertical Scale: 3050 feet = 1 inch



W. & A. K. Johnston

the third rank, followed by France and Russia. The United States produce 33 per cent.[1] of the gold yield of the whole world, 50 per cent. of the silver, 22 per cent. of the pig iron,[2] 29 per cent. of the steel, and about 25 per cent. of the lead.

Mexico has been renowned for its gold and silver mines ever since the Spaniards first took possession of it, and its production is still very considerable. Indeed, after the United States, it still produces far more silver than any other country in the world. The average annual output of silver during the twenty-five years 1851 to 1875 is estimated by Dr Adolf Soetbeer at 501,520 kilogrammes, or 16,124,235 oz.;[3] whilst the average annual output of gold during the same period was 1785 kilogrammes, or 57,389 oz. Tin ore occurs in considerable quantities in Mexico, and is likely to be worked on a large scale as soon as the tin district is opened up by a railway.

Central America possesses numerous gold mines.

South America.—Venezuela produces gold, copper, and a little lead. The copper is found at Aroa near the north coast, and the gold in the province of Guiana, which is now producing upwards of 100,000 oz. annually. It is highly probable that the existence of this gold was known to the Indians, who reported it to Sir Walter Raleigh, and so led him to undertake his unfortunate expedition in search of "El Dorado." French Guiana contains workable deposits of gold, and yielded 72,168 oz. in 1880.

The chain of the Andes forms a long belt of mineral-producing country. Beginning with the United States of Colombia we have a country rich in gold,—the State of Antiquoia being especially favoured in this respect. The annual yield of all the states is about 200,000 oz. Colombia has mines of rock salt, yielding 19,000 tons a year, and the emerald mine at Muzo has long been famous. Peru is renowned for its silver mines; the best-known are those of Cerro de Pasco, situated at an elevation of 14,000 feet above the sea-level. Passing into Bolivia, we must notice the silver mines of Potosi, the wealth of which is proverbial. Chili is best known as the principal copper-producing country of South America; but its silver mines are not unimportant, and beds of nitrate of soda are largely wrought.

The most remarkable gold mines of Brazil lie in the province of Minas Geraes, whilst diamonds are obtained in that of Matto Grosso. In the Argentine Republic gold, silver, and copper mines are worked, especially in the provinces on the eastern flanks of the Andes.

The total annual output of the precious metal in South America is estimated to be upwards of 300,000 oz. of gold, and 2,000,000 oz. of silver. In 1877 Chili exported 35,128 metric tons of metallic copper, in addition to ore and regulus.

Australia.—Australia is remarkably rich in minerals, especially gold (see GOLD, vol. x. p. 744), tin, and copper, and its coal deposits are likely to be largely utilized in the future.

Queensland, though a young colony, has already made itself famous for gold and tin, and it also possesses vast resources of coal and copper, in addition to the ores of other metals. The quantity of gold sent by escort from the different gold fields was 204,388 oz. in 1880, in addition to what was carried by private hands. Tin ore was first worked in 1872 near the border of the colony with New South Wales, and large quantities of stream tin have been obtained from very shallow alluvial diggings near Stanthorpe. Like gold, the tin ore is not confined to one district; it occurs and is worked at the North Palmer diggings; a little to the south is Great Western, rich in tin ore, and so is Herberton to the north-east on the other side of the Dividing range.

In 1881 New South Wales[4] produced minerals and metals worth £2,373,191, viz., 149,627 oz. of gold, 1,775,224 tons of coal, 8200 tons of tin, 5493 tons of copper, 6560 tons of iron, besides silver, oil-shale, and antimony. In addition to the facts concerning the occurrence of gold already mentioned (*loc. cit.*), it is interesting to note that auriferous conglomerates containing the precious metal in payable quantities have been discovered and worked in this colony in rocks of the age of the Coal Measures.[5] The most important tin district is that of Vegetable Creek in New England, which from 1872 to 1880 produced 20,988 tons of tin ore. The accompanying map (fig. 105[6]) shows the recent alluvium which has hitherto been

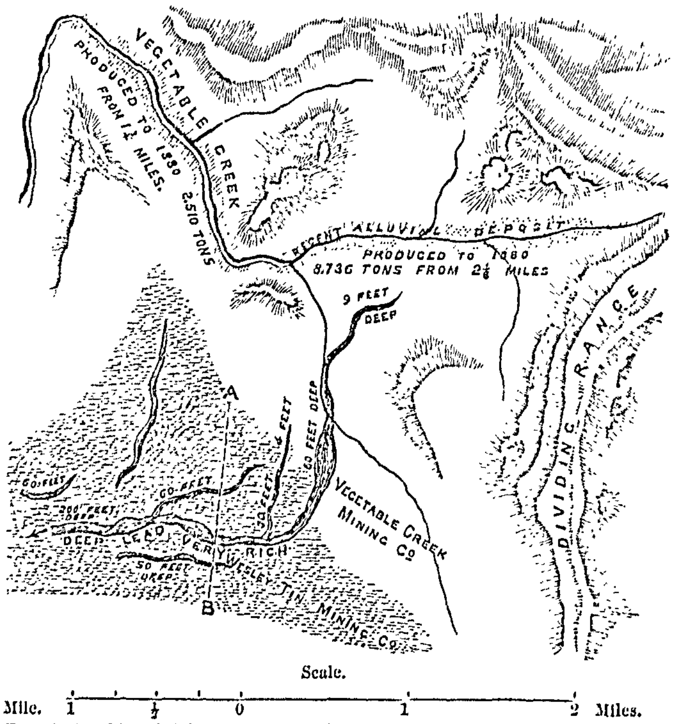


FIG. 105.—Sketch Map of Part of Vegetable Creek, New South Wales, showing recent and ancient tin deposits. The stippled part represents tin-bearing alluvium. The shaded part AB denotes basalt which has covered the lower portions of the ancient tin-bearing alluvia (deep leads), as explained in fig. 106. The rest is granite.

the main source of the supply, and the deep leads which, as far as explored at present, promise still greater riches. The section (fig. 106[6]) shows that these deep leads, like those of the gold fields

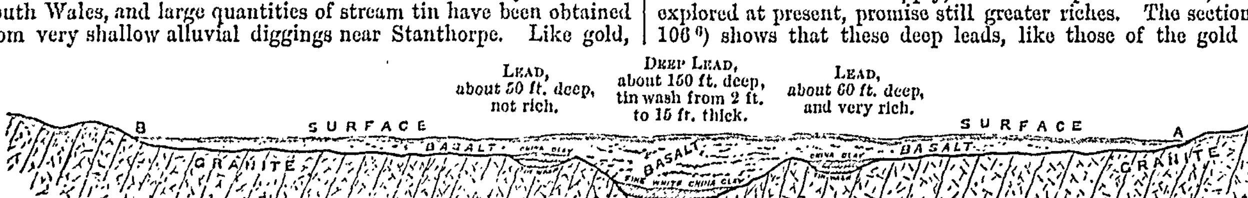


FIG. 106.—Enlarged Section (on AB of fig. 105) across Deep Leads in Vegetable Creek, New South Wales.

(GOLD, vol. x. p. 743), are old alluvia preserved under a capping of basaltic lava. There are also numerous tin lodes which are beginning to be worked.

Victoria heads the list of gold-producing British colonies, having yielded in 1882[7] as much as 864,610 oz., of which 352,078 oz. were derived from alluvial deposits, and 512,532 oz. from quartz mines. 1077 tons of tin ore were raised and 375 tons of antimony ore.

South Australia is the great copper-producing province, though the yield is not so great as it was ten years ago. The principal mines now at work are on Yorke's Peninsula. In 1881[8] South Australia produced 3824 tons of copper, worth £263,370, and 21,638 tons of copper ore, worth £154,926.

In 1881 Western Australia exported 1400 tons of lead ore, valued at £11,204.

Tasmania, like some parts of Australia, is rich in tin ore, which is now obtained principally from an alluvial deposit at Mount Bischoff. The ore is now almost entirely smelted in the colony, and in 1880 the exports were 3951 tons of metal and 3 tons of ore, worth altogether £341,736.

New Zealand furnishes a considerable amount of gold from quartz reefs and alluvial diggings. The annual exports during the ten years 1862 to 1872 were often 600,000 and even 700,000 oz. Of late years the yield has gradually diminished, and in 1880 only 303,215 oz., valued at £1,220,263, were exported. Silver is exported to the

[1] Clarence King, *op. cit.*, p. 93.
[2] James M. Swank, *Statistics of the Iron and Steel Productions of the United States*, Washington, 1881, p. 179.
[3] Dr Adolf Soetbeer, *Edelmetall-Produktion*, Gotha, 1879, p. 60.
[4] *Annual Report of the Department of Mines, New South Wales, for the year* 1881, Melbourne, 1882, p. 8.
[5] *Annual Report of the Department of Mines, New South Wales, for the year* 1876, Sydney, 1877, p. 173.
[6] Furnished by Mr W. H. Wesley.
[7] *Mineral Statistics of Victoria for the year* 1882, Melbourne, 1883 p. 7.
[8] *Statistical Register of the Province of South Australia for the year* 1881 Adelaide, 1882

extent of 20,000 to 30,000 oz. annually; it is mainly derived from the gold obtained in the Thames district, which contains about 30 per cent. of the less valuable metal. Coal is worked in several places, but the total output is at present comparatively small.

New Caledonia.—The discovery of nickel ore in this island by M. Garnier in 1867 was one of great mineralogical interest, and it has since borne fruits of considerable commercial importance. The New Caledonia ores are hydrous silicates of nickel and magnesium, which occur in veins in serpentine, and contain from 7 to 18 per cent. of metal. The mineral is found on the Mont d'Or not far from Noumea. Most of the ore is sent to France to be treated.

To the list of works on mining mentioned in the article COAL (vol. vi. p. 81) the following may be added:—Callon, *Cours d'exploitation des Mines*, Paris, 1874, and English translation by C. Le Neve Foster and W. Galloway; Serlo, *Leitfaden zur Bergbaukunde*, Berlin, 1878; Zoppetti, *Arte mineraria*, Milan, 1882; A. von Groddeck, *Die Lehre von den Lagerstätten der Erze*, Leipsic, 1879; P. von Rittinger, *Lehrbuch der Aufbereitungskunde*, Berlin, 1867; *Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen*, Freiberg, annually; *Annual Reports of H.M. Inspectors of Mines*; *Preliminary Report of Her Majesty's Commissioners Appointed to Inquire into Accidents in Mines*, London, 1881; *Annales des Mines*, Paris, 6 parts published yearly; *The Engineering and Mining Journal*, New York, published weekly; *Transactions of the American Institute of Mining Engineers*, Philadelphia; *Die berg- und hüttenmännische Zeitung*, Leipsic, weekly; *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, Vienna, weekly. (C. L. N. F.)

MINISTRY. Ever since the introduction of monarchical institutions into England the sovereign has always been surrounded by a select body of confidential advisers to assist the crown in the government of the country. At no period could a king of England act, according to law, without advice in the public concerns of the kingdom; the institution of the crown of England and the institution of the privy council are coeval. At the era of the Norman Conquest the king's council, or as it is now called the privy council, was composed of certain select members of the aristocracy and great officers of state, specially summoned by the crown, with whom the sovereign usually advised in matters of state and government. In the earlier stages of English constitutional history the king's councillors, as confidential servants of the monarch, were present at every meeting of parliament in order to advise upon matters judicial in the House of Lords; but in the reign of Richard II. the privy council dissolved its judicial connexion with the peers and assumed an independent jurisdiction of its own. It was in the reign of Henry VI. that the king's council first assumed the name of privy council, and it was also during the minority of this sovereign that a select council was gradually emerging from out of the larger body of the privy council, which ultimately resulted in the institution of the modern cabinet. Since the Revolution of 1688, and the development of the system of parliamentary government, the privy council has dwindled into comparative insignificance when contrasted with its original authoritative position. The power once swayed by the privy council is now exercised by that unrecognized select committee of the council which we call the cabinet. The practice of consulting a few confidential advisers instead of the whole privy council had been resorted to by English monarchs from a very early period; but the first mention of the term cabinet council in contradistinction to privy council occurs in the reign of Charles I., when the burden of state affairs was intrusted to the committee of state which Clarendon says was enviously called the "cabinet council." At first government by cabinet was as unpopular as it was irregular. Until the formation of the first parliamentary ministry by William III. the ministers of the king occupied no recognized position in the House of Commons; it was indeed a moot point whether they were entitled to sit at all in the lower chamber, and they were seldom of one mind in the administration of matters of importance. Before the Revolution of 1688 there were ministers, but no ministry in the modern sense of the word; colleague schemed against colleague in the council chamber, and it was no uncommon thing to see ministers opposing one another in parliament upon measures that ought to have been supported by a united cabinet. As the exchange from government by prerogative to government by parliament, consequent upon the Revolution of 1688, developed, and the House of Commons became more and more the centre and force of the state, the advantage of having ministers in the legislature to explain and defend the measures and policy of the executive Government began gradually to be appreciated. The public authority of the crown being only exercised in acts of administration, or, in other words, through the medium of ministers, it became absolutely necessary that the advisers of the sovereign, who were responsible for every public act of the crown as well as for the general policy they had been called upon to administer, should have seats in both Houses of Parliament. The presence of ministers in the legislature was the natural consequence of the substitution of government by parliament for the order of things that had existed before 1688. Still nearly a century had to elapse before political unanimity in the cabinet was recognized as a political maxim. From the first parliamentary ministry of William III. until the rise of the second Pitt divisions in the cabinet were constantly occurring, and a prime minister had more to fear from the intrigues of his own colleagues than from the tactics of the opposition. In 1812 an attempt was made to form a ministry consisting of men of opposite political principles, who were invited to accept office, not avowedly as a coalition Government, but with an offer to the Whig leaders that their friends should be allowed a majority of one in the cabinet. This offer was declined on the plea that to construct a cabinet on "a system of counteraction was inconsistent with the prosecution of any uniform and beneficial course of policy." From that date it has been an established principle that all cabinets are to be formed on some basis of political union agreed upon by the members composing the same when they accept office together. It is now also distinctly understood that the members of a cabinet are jointly and severally responsible for each other's acts, and that any attempt to separate between a particular minister and his colleagues in such matters is unfair and unconstitutional.

The leading members of an administration constitute the CABINET (*q.v.*). The members of an administration who are sworn of the council, but who are not cabinet ministers, are the lord-lieutenant of Ireland, the vice-president of the council for education, the judge advocate general, and the chief officers of the royal household. The subordinate members of an administration who are never in the cabinet, and who are seldom raised to the distinction of privy councillors, are the junior lords of the treasury, the joint-secretaries to the treasury, the paymaster-general, the junior lords of the admiralty, the parliamentary under-secretaries of state, and the law officers of the crown.

During the present century the power of ministers has been greatly extended, and their duties more distinctly marked out. Owing to the development of the system of parliamentary government, much of the authority which formerly belonged to English sovereigns has been delegated to the hands of responsible ministers. As now interpreted, the leading principles of the British constitution are the personal irresponsibility of the sovereign, the responsibility of ministers, and the inquisitorial power of parliament. At the head of affairs is the prime minister, and the difference between theory and practice is curiously exemplified by the post he fills. The office is full of anomalies. Like the cabinet council the prime minister is unknown to the law

and the constitution, for legally and according to the fictions of the constitution no one privy councillor has as such any superiority over another, yet practically the premier is the pivot on which the whole administration turns. He is the medium of intercourse between the cabinet and the sovereign; he has to be cognizant of all matters of real importance that take place in the different departments so as to exercise a controlling influence in the cabinet; he is virtually responsible for the disposal of the entire patronage of the crown; he selects his colleagues, and by his resignation of office dissolves the ministry. Yet, though entrusted with this power, and wielding an almost absolute authority, he is in theory but the equal of the colleagues he appoints and whose opposition he can silence by the threat of dissolution. The prime minister is nominated by the sovereign. "I offered," said Sir Robert Peel on his resignation of office, "no opinion as to the choice of a successor. That is almost the only act which is the personal act of the sovereign; it is for the sovereign to determine in whom her confidence shall be placed." Yet this selection by the crown is practically limited. No prime minister could carry on the government of the country for any length of time who did not possess the confidence of the House of Commons; and royal favour, if it were ever invidiously exercised, would ultimately have to yield to a regard for the public interests. As a general rule the prime minister holds the office of first lord of the treasury, either alone or in connexion with that of chancellor of the exchequer. Before 1806 the premiership was occasionally held in connexion with different other offices,—a secretaryship of state, the privy seal, and the like,—but it is now almost invariably associated with the post of first lord of the treasury. With the exception of the premier, whose duties are more general than departmental, the work of the other members of the administration is exemplified by the title of the offices to which they are called. The lord chancellor, in addition to the jurisdiction which he exercises in his judicial capacity, is prolocutor of the House of Lords by prescription, the keeper of the sovereign's conscience, the general guardian of all infants, idiots, and lunatics, and to him belongs the appointment of all the justices of the peace throughout the kingdom. In former times the lord chancellor was frequently prime minister; the earl of Clarendon in the reign of Charles II., however, was the last who occupied that position. The lord president of the council, who is always a member of the Upper House, presides over the department of the privy council, exercises a general superintendence over the education department, and has to frame minutes of council upon subjects which do not belong to any other department of state. Subordinate to his department are separate establishments in relation to public health, the cattle plague, and quarantine. The post of lord privy seal is one of great trust, though its duties are not very onerous, since they simply consist in applying the privy seal once or twice a week to a number of patents. Ever since the days of Henry VIII. the privy seal has been the warrant of the legality of grants from the crown and the authority of the lord chancellor for affixing the great seal. The lord privy seal is always a member of the cabinet. As his official duties are light he is at liberty to afford assistance to the administration in other ways, and he has often to attend to matters which require the investigation of a member of the Government.

The secretaries of state are among the most important members of the ministry, and within the present century their number has been increased and their duties more specially consolidated. The ancient English monarchs were always attended by a learned ecclesiastic, known at first as their clerk, and afterwards as secretary, who conducted the royal correspondence; but it was not until the end of the reign of Queen Elizabeth that these functionaries were called secretaries of state. Upon the direction of public affairs passing from the privy council to the cabinet after 1688, the secretaries of state began to assume those high duties which now render their office one of the most influential of an administration. Until the reign of Henry VIII. there was generally only one secretary of state, but at the end of his reign a second principal secretary was appointed. Owing to the increase of business consequent upon the union of Scotland, a third secretary, in 1708, was created, but a vacancy occurring in this office in 1746 the third secretaryship was dispensed with until 1768, when it was again instituted to take charge of the increasing colonial business. However, in 1782 the office was again abolished, and the charge of the colonies transferred to the home secretary; but owing to the war with France in 1794 a third secretary was once more appointed to superintend the business of the war department, and seven years later the colonial business was attached to his department. In 1854 a fourth secretary of state for the exclusive charge of the war department and in 1858 a fifth secretaryship for India were created. There are therefore now five principal secretaries of state, four of whom, with their political under-secretaries, occupy seats in the House of Commons. One of these secretaries of state is always a member of the House of Lords. The secretaries of state are the only authorized channels through which the royal pleasure is signified to any part of the body politic, and the counter-signature of one of them is necessary to give validity to the sign manual; thus, while the personal immunity of the sovereign is secured, a responsible adviser for every act is provided who has to answer for whatever course the crown has pursued. The secretaries of state constitute but one office, and are coordinate in rank and equal in authority. Each is competent in general to execute any part of the duties of the secretary of state, the division of duties being a mere matter of arrangement. These duties are of the deepest importance to the welfare of the nation. The home secretary controls all matters relating to the internal affairs of the country: he is responsible for the preservation of the public peace and for the security of life and property throughout the kingdom; he exercises extensive powers over the civil and military authorities of the country, and has a direct controlling power over the administration of justice and police in the municipal boroughs, over the police in and around London, and over the county constabulary; and he is especially responsible for the exercise of the royal prerogative in the reprieve or pardon of convicted offenders or the commutation of their sentences. The foreign secretary, as his name implies, is the official organ of the crown in all communications between Great Britain and foreign powers: he negotiates all treaties or alliances with foreign states, protects British subjects residing abroad, and demands satisfaction for any injuries they may sustain at the hands of foreigners. The secretary of state for the colonies has to superintend the government of the various colonial possessions of the British crown: he appoints the governors over the different dependencies of the crown, and sanctions or disallows the enactments of the colonial legislatures. This latter power has of late years been much curtailed owing to the establishment of responsible government in most of the colonies; still it is the duty of the secretary of the colonies to correspond with the colonial governors and to offer such suggestions as may be expedient to assist the deliberations of the colonial councils and to promote the welfare of colonial subjects. Until the year 1854 the direction of military affairs was practically divided between the commander-in-chief at the horse guards, the board of ordnance, the secretary at war, and the secretary of state for war and the colonies. Upon the declaration of hostilities, however, against Russia in 1854, the duties of war minister were separated from those of colonial secretary, and a secretary of state for war appointed, in whose hands the supreme and responsible authority over the whole military business of the country formerly transacted by the various departments was placed. The actions of the commander-in-chief are subject to the approval of the secretary of state for war. The duties of the commander-in-chief embrace the discipline and patronage of the army and the direct superintendence of the *personnel* of the army; with the exception of those duties, everything connected with the management of the army in peace or war (its *matériel* and civil administration, &c.) remains in the hands of the war minister. The subordinate position of the commander-in-chief is the result of the British system of parliamentary government. The secretary of state for war is the minister of the crown and not of parliament; although he is responsible to parliament for the advice he may give to the sovereign, yet it is in the execution of the royal authority and prerogative that he is superior to the officer commanding in chief. The principle of the constitutional army is that command, preferment, and honour come to it from the crown; but the general principle is equally undisputed that for all pecuniary remuneration it is made to depend on parliament. By the constitution the crown exercises its authority only through responsible advisers, and hence it follows that the secretary of state for war is supreme over any authority in the army, including the officer commanding in chief. From 1784 to 1858 the territories belonging to the British crown in

the East Indies were governed by a department of state called the board of control in conjunction with the court of directors of the East India Company. In 1858 this double government was abolished, and the entire administration of the British empire in India was assumed by the crown, and all the powers formerly exercised by the East India Company and the board of control were transferred to a fifth principal secretary of state. The secretary for India is responsible for everything connected with the Indian Government at home and abroad; the whole of the Indian revenues are at his disposal, and the governor-general of India is subject to his control. To assist him in his labours, and to act as a check upon the exercise of his otherwise arbitrary administrative powers, this secretary has the aid of a council of state for India, consisting of fifteen persons, of which, however, he is the president. The members of the council for India cannot sit in the House of Commons.

The duties of the other members of the ministry can be briefly dismissed. The chancellor of the exchequer at present exercises all the powers which formerly devolved upon the treasury board; he has the entire control of all matters relating to the receipt and expenditure of public money; he frames the annual estimates of the sums required to defray the expenditure of government in every branch of the public service; and it is his duty to lay before the country the annual statement of the estimated expenses of government and of the ways and means by which it is proposed to defray those charges, including the imposition or remission of taxes. The first lord of the admiralty (since the abolition of the office of lord high admiral), with the aid of the junior lords who are called the lords of the admiralty, conducts the administration of the entire naval force of the empire both at home and abroad, and is responsible to parliament for all his political proceedings; as the admiralty is but an executive board, it is, however, subject on certain matters —the number of men required for the naval service, the distribution of the fleet, the strength of foreign squadrons, &c.—to the control of the cabinet. The president of the board of trade takes cognizance of all matters relating to trade and commerce, and has to protect the mercantile interests of the United Kingdom; until 1864 it was not necessary for the president to have a seat in the cabinet, but since that date he has always been a cabinet minister in order to insure for his advice on commercial matters a due consideration; in 1867 the office of vice-president of the board was abolished. The chancellor of the duchy of Lancaster exercises jurisdiction over all matters of equity relating to lands held of the crown in right of the duchy of Lancaster; the office is, however, practically a sinecure, and is usually filled by a leading statesman whose time is at the service of the Government for the consideration of such important questions as do not come within the province of other departments. In 1832 the public works and buildings of Great Britain were for the first time placed under the control of a responsible minister of the crown, and were assigned to the charge of the commissioners of woods and forests; but in 1851 the department of public works was separated from the woods and forests and erected into a board under the name of the office of her majesty's works and public buildings. The first commissioner of works is the head of the board, and in his hands is placed the custody of the royal palaces and parks and of all public buildings not specially assigned to the care of other departments. Since the establishment of his office the first commissioner has frequently had a seat in the cabinet. The duties of the postmaster-general, of the president of the local government board, and of the minor members of the administration are so obvious from the titles of the offices they hold as not to call for any special mention.

The prime minister is responsible for the distribution of the chief offices of government between the two Houses of Parliament. Owing to the development of the House of Commons within the present century it is now considered advisable that a larger proportion of cabinet ministers should have seats in that chamber than was formerly the case. In the first cabinet of George III. only one of its members was in the House of Commons and thirteen in the House of Lords. In 1783 Mr Pitt was the sole cabinet minister in the Commons. In 1801 four cabinet ministers were in the Commons and five in the Lords. In 1804 Mr Pitt and Lord Castlereagh were, out of a cabinet of twelve, the only ministers in the Commons. In the Grenville ministry ("All the Talents"), of a cabinet of eleven, seven were in the Lords and four in the Commons. In 1809, of Mr Perceval's cabinet, six were peers and four commoners. In 1812, of Lord Liverpool's cabinet, ten were peers and only two commoners. In 1818, out of a cabinet of fourteen, six were commoners; and in 1822, out of a cabinet of fifteen, nine were peers. Since the Reform Act of 1832, however, the leading members of Government have been more equally apportioned between the two Houses.

See May, *Constitutional History of England*; Cox, *Institutions of the English Government*; Alpheus Todd, *On Parliamentary Government*; Cooke, *History of Party*. (A. C. E.)

MINK. The genus *Putorius*, belonging to the family *Mustelidæ* or Weasel-like animals (see MAMMALIA, vol. xv. p. 440), contains a few species called Minks, distinguished from the rest by slight structural modifications, and especially by semiaquatic habits. They form the subgenus *Lutreola* of Wagner, the genus *Vison* of Gray. As in other members of the genus, the dental formula is $i\ \frac{3}{3}$, $c\ \frac{1}{1}$, $p\ \frac{3}{3}$, $m\ \frac{1}{2}$; total 34. They are distinguished from the Polecats, Stoats, and Weasels, which constitute the remainder of the group, by the facial part of the skull being narrower and more approaching in form that of the Martens, by the premolar teeth (especially the first of the upper jaw) being larger, by the toes being partially webbed, and by the absence of hair in the intervals between the naked pads of the soles of the feet. The two best-known species, so much alike in size, form, colour, and habits that although they are widely separated geographically some zoologists question their specific distinction, are *P. lutreola*, the *Nörz* or *Sumpf-otter* (Marsh-Otter) of eastern Europe, and *P. vison*, the Mink of North America. The former inhabits Finland, Poland, and the greater part of Russia, though not found east of the Ural mountains. Formerly it extended westward into central Germany, but it is now very rare, if not extinct, in that country. The latter is found in places which suit its habits throughout the whole of North America. Another form, *P. sibiricus*, from eastern Asia, of which much less is known, appears to connect the true Minks with the Polecats.

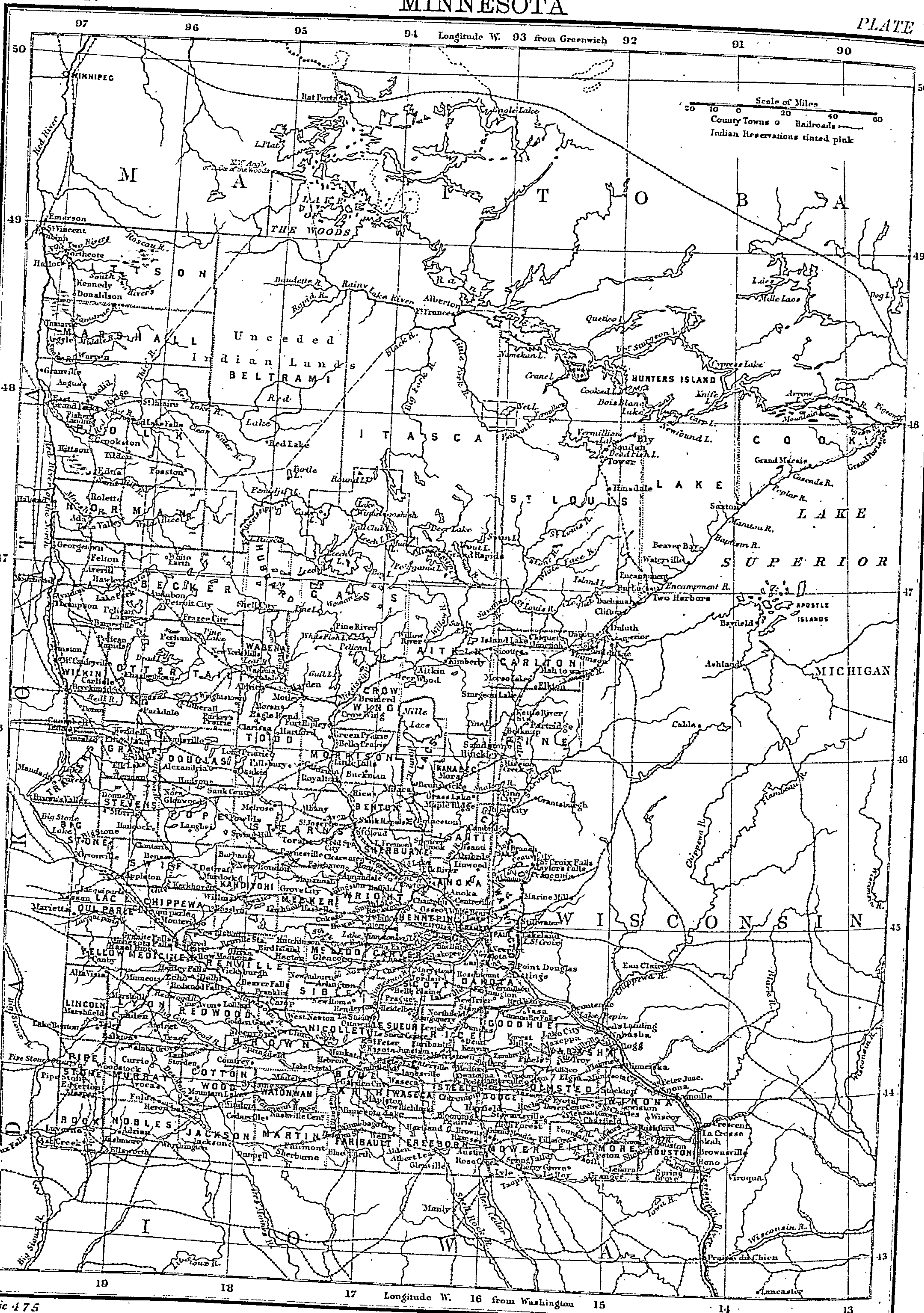
The name may have originated in the Swedish *maenk* applied to the European animal. Captain John Smith, in his *History of Virginia* (1626), at p. 27, speaks of "Martins, Powlecats, Weesels, and Minkes," showing that the animal must at that time have been distinguished by a vernacular appellation from its congeners. By later authors, as Lawson (1709) and Pennant (1784), it is often written "Minx." For the following description, chiefly taken from the American form (though almost equally applicable to that of Europe) we are mainly indebted to Elliott Coues's *Fur-bearing Animals of North America*, 1877.

In size it much resembles the English Polecat,—the length of the head and body being usually from 15 to 18 inches, that of the tail to the end of the hair about 9 inches. The female is considerably smaller than the male. The tail is bushy, but tapering at the end. The ears are small, low, rounded, and scarcely project beyond the adjacent fur. The pelage consists of a dense, soft, matted under fur, mixed with long, stiff, lustrous hairs on all parts of the body and tail. The gloss is greatest on the upper parts; on the tail the bristly hairs predominate. Northern specimens have the finest and most glistening pelage; in those from southern regions there is less difference between the under and over fur, and the whole pelage is coarser and harsher. In colour, different specimens present a considerable range of variation, but the animal is ordinarily of a rich dark brown, scarcely or not paler below than on the general upper parts; but the back is usually the darkest, and the tail is nearly black. The under jaw, from the chin about as far back as the angle of the mouth, is generally white. In the European Mink the upper lip is also white, but, as this occasionally occurs in American specimens, it fails as an absolutely distinguishing character. Besides the white on the chin, there are often other irregular white patches on the under parts of the body. In very rare instances the tail is tipped with white. The fur, like that of most of the animals of the group to which it belongs, is an important article of commerce.

The principal characteristic of the Mink in comparison with its congeners is its amphibious mode of life. It is to the water what the other Weasels are to the land, or Martens to the trees, being as essentially aquatic in its habits as the Otter, Beaver, or Musk-rat, and spending perhaps more of its time in the water than it does on land. It swims with most of the body submerged, and dives with perfect ease, remaining long without coming to the surface to breathe. It makes its nest in burrows in the banks of streams, breeding once a year about the month of April, and producing five or six young at a birth. Its food consists of frogs, fish, freshwater molluscs and crustaceans, as well as mice, rats, musk-rats, rabbits, and small birds. In common with the other animals of the genus, it has a very peculiar and disagreeable effluvium, which, according to Coues, is more powerful, penetrating, and lasting than that of any animal of the country except the Skunk. It also possesses the courage, ferocity, and tenacity of life of its allies. When taken young, however, it can be readily tamed, and lately Minks have been extensively bred in captivity in America both for the sake of their fur and for the purpose of using them in like manner as Ferrets in England, to clear buildings of rats. (W. H. F.)

MINNEAPOLIS, the county seat of Hennepin county, Minnesota, United States, and in 1880 the first city of the State as regards population, lies on both banks of the

MINNESOTA



ENCYCLOPÆDIA BRITANNICA. NINTH EDITION.

Mississippi, at the falls of St Anthony, 14 miles by river above St Paul. The east side was first settled, under the name of St Anthony, which was incorporated as a city in 1860. The west side settlement, named Minneapolis, was incorporated as a city in 1867, and soon surpassed St Anthony in population. In 1872 the two cities were united under the name of Minneapolis. The chief industries are the manufacture of flour and of lumber, for which the falls supply abundant water-power. The Mississippi here flows over a limestone bed resting upon a friable white sandstone; hence erosion is rapid, and the river banks show that the falls have receded from a position at the mouth of the Minnesota river. In 1851 90 feet of the limestone gave way at once; and, as the rock bed extends but 1200 feet above the present site of the falls, the destruction of the water-power was threatened. This has been averted by the construction of an apron, or inclined plane, of timber, with heavy cribwork at the bottom, and the building of a concrete wall in the bed of sandstone behind the falls and underneath the channel of the river. For this work the United States Government appropriated $550,000 and the citizens of Minneapolis contributed $334,500. The city has twenty-seven flour-mills, which can produce 29,272 barrels a day. The total product for the year ended September 1, 1882, was 2,301,667 barrels. The shipments of lumber for 1880 were 164,620,000 feet. The population in 1870 was 18,079; and in 1880, 46,887.

MINNESÄNGER. See GERMANY, vol. x. p. 525.

MINNESOTA, one of the north-western States of the American Union, extending from 43° 30′ N. lat. to the British Possessions (about 49° N. lat.), and from Wisconsin and Lake Superior on the east to Dakota on the west, between the meridians of 89° 39′ and 97° 5′ W. long. Its area, including half of the lakes, straits, and rivers along its boundaries, except Rainy Lake and Lake of the Woods, amounts to 83,365 square miles.

The surface of Minnesota is diversified by few elevations of any great height. In general it is an undulating plain, breaking in some sections into rolling prairie, and traversed by belts of timber. It has an average elevation above sea-level of about 1000 feet. The watershed of the north (which determines the course of the three great continental river systems) and that of the west are not ridges or hills, but elevations whose inclination is almost insensible. The southern and central portions of the State are chiefly rolling prairie, the upper part of which is crossed from N.W. to S.E. by the forest belt known as the Big Woods,—a stretch of deciduous forest trees with an area of about 5000 square miles. North of the 47th parallel, the great Minnesota pine belt reaches from Lake Superior to the confines of the Red River valley, including the region of the headwaters of the Mississippi and its upper tributaries, as well as those of the Superior streams. North of the pine region there is but a stunted growth of tamarack and dwarf pine. In the north-east are found the rugged elevations of the granite uplift of the shores of Lake Superior, rising to a considerable height; while in the north-west the surface slopes away to the level prairie reaches of the Red River valley. The surface elevation of the State varies from 800 to 2000 feet above sea-level. A short line of hills in the north-east reaches the latter altitude, while only the valleys of the Red River, the Mississippi, and the Minnesota fall below the former.

Geology and Soil.—The geology has not yet been mapped out with the precision attained in other States. The great central zone, from Lake Superior to the south-western extremity of the State, is occupied by granitic and metamorphic rocks, succeeded, in the south-east, by narrower bands of later formation. Within the great Azoic area lies the central watershed of the continent, from which the St Lawrence system sends its waters towards the Atlantic, the Mississippi towards the Gulf of Mexico, and the Red River of the North to Hudson's Bay. These primordial rocks carry back the geologic history of Minnesota to pre-Silurian times. They form in the north-east, in the neighbourhood of Lake Superior, an extremely rough and hilly country, but as they reach the central and south-western portions of the State they for the most part disappear beneath the surface drift. This central belt is succeeded, on the south and east, by a stretch of sandstone, partially the true red Potsdam and partially a similar but lighter-coloured stratum, which some have proposed to designate the St Croix Sandstone. Isolated beds of sandstone are found in various parts of the State. The north-western corner, stretching east from the Red River valley, is believed to be Cretaceous; but the great depth of drift and alluvium, disturbed by no large rivers, prevents a positive conclusion. The Lower Magnesian limestone underlies the extreme south-eastern portion of the State, and extends along the west side of the Mississippi to a point a little below St Paul; thence it takes a course almost semicircular, and finally passes out of the State at the south-western boundary. The Trenton limestone occupies a large field in the south and south-east; it comes to the surface in long irregular bands, and an island of it underlies the cities of Minneapolis and St Paul with the adjacent districts. The Galena limestone, the Masquoketa shales, the Niagara limestone, and the rocks of the Devonian age in turn prevail in the other counties of the south and east; while the existence of the St Peter sandstone would scarcely be known but for its outcropping along the bluffs of the Mississippi, and at the famous waterfall of Minnehaha. From these various formations numerous kinds of stone valuable for building purposes are obtained. The grey granite of St Cloud is extremely hard and enduring. The Lower Magnesian furnishes two especially handsome building stones,—the pink limestone known as Kasota stone, and the cream-coloured stone of Red Wing, both easily worked, and hardening by exposure to atmospheric changes. Naturally, from its location underneath the principal cities of the State, the Trenton limestone is the most widely used. Sand suitable for glass-making, and argillaceous deposits abound. The clays which make up so large a portion of the surface drift of the State are almost wholly of glacial origin. Overlying the deposits of sand, gravel, boulders, and clay is, in most portions of the State, a sandy loam, very finely divided, rich in organic matter, deep brown or black in colour, and of the greatest fertility. It is this soil which has given to the State its reputation for productiveness. Its depth varies from 2 to 5 feet in various parts of the State, and it has been described by Dr Owen as "excellent in quality, rich as well in organic matter as in those mineral salts which give rapidity to the growth of plants, while it has that durability which enables it to sustain a long succession of crops."

Rivers and Lakes.—The State holds a unique place in the great water systems of the continent. The Mississippi, which takes its rise north of the centre of the state in Lake Itaska and its contributory lakelets, leaves the state limits a great river, half a mile wide, and from 5 to 20 feet deep. It drains with its tributaries all the southern and central portions and a large area of the northern part of the State. It is navigable as far as St Paul, and at Minneapolis the falls of St Anthony afford unrivalled facilities for manufacturing. Of the many affluents of the Mississippi the most important is the Minnesota, which after a course of about 440 miles flows into the main stream at Fort Snelling, 3 miles above St Paul. The source of the Minnesota is but 1 mile from Lake Traverse, the origin of the Red River of the North, and it is navigable during the high-water season for about 238 miles. Its principal tributaries are the Blue Earth, Chippewa, Redwood, Lac qui Parle, and Pomme de Terre. The Red River system drains the north-western part of the State, and its waters

finally pass into Hudson's Bay, as also do those from the country drained by streams flowing to the Rainy Lake river and the lakes along the northern boundary line. East of this lies the region tributary to Lake Superior and the St Lawrence system. This comprises an area within the State estimated at 9000 square miles. Its principal river is the St Louis. There are altogether about 2796 miles of navigable water in Minnesota.

The number of lakes is estimated at seven thousand. They are of all sizes, and are found chiefly in the northern two-thirds of the State. They have been classified geologically into glacial or drift lakes, fluviatile or river lakes, occupying basins on river courses, and lakes having rock basins either scooped out by the action of glaciers or formed by the relative position of different geological formations. By far the greater number give evidence of glacial action in their origin. They abound over the region most deeply covered by the surface drift, and are especially prevalent in morainic districts, forming the southern fringe of the lacustrine area of North America. With the melting of the ice-sheet which once overspread Minnesota its innumerable lakes came into existence; and the gentle acclivity of its slopes, precluding rapid erosive action, has tended to give permanence to the depressions constituting their basins. The census returns give 4160 square miles of water surface within the State. Most of the lakes are exceedingly picturesque in their surroundings. Forests skirt their shores, which are seldom marshy; and their waters, abounding in various kinds of fish, are clear and cool. Besides the sanitary advantages afforded by the lakes, as supplying places for recreation and delightful summer resorts, they affect the climate to some extent, tempering the extremes commonly experienced in northern latitudes. The fact that many of the lakes are gradually drying up must be explained by agricultural operations. The largest lakes, exclusive of Superior, lying wholly or in part in Minnesota are as follows:—Lake of the Woods, 612 square miles; Red, 342; Mille Lacs, 198; Leech, 194; Rainy, 146; Winnibigoshish, 78; and Vermilion, 63.

Flora and Fauna.—The flora and fauna present no marked differences from those of other States in the same latitude. In a partial list of the birds of Minnesota, two hundred and eighty-one species are enumerated. Of winter birds fifty-two species have been classified, twenty-three of them being permanent residents.

Climate.—The State lies so far north as to have a low mean annual temperature, and so far inland as to have the characteristic continental climate. Its elevation above sea-level gives an agreeable rarefaction to the atmosphere, and makes the prevalence of fogs and damp weather unknown. Between June and January there is an annual variation from the summer heat of southern Ohio to the winter cold of Montreal. The winter, usually commencing in November, and continuing till near the end of March, is not a period of intense continued cold, but is subject to considerable variations. As a rule, the comparative dryness of the atmosphere neutralizes the severest effect of excessive cold. The snowfall is extremely light during most of the winter, but as spring approaches precipitation becomes greater, and there are frequently heavy snowfalls in February and March. The change from winter to summer is rapid, vegetation sometimes seeming to leap into full and active growth within the space of a few weeks. The summer months bring days of intense heat, but, with comparatively rare exceptions, the nights are deliciously cool. Hot days and cool nights make the ideal weather for a good wheat crop; and the forcing heats of summer produce in luxuriant growth the vegetable life which belongs to the middle States. The Smithsonian chart assigns to Minnesota an average temperature for the hottest week in summer of from 85° to 90°, and for the coldest week in winter from 10° to 20° below zero. The mean annual average, for all below 47° of latitude, it gives as 40°. Observations at St Paul, extending over a period of more than thirty-five years, show the following mean temperatures:—spring, 45°·6; summer, 70°·6; autumn, 40°·9; winter, 16°·1; average, 44°·6. The average annual rainfall is about 25·5 inches. While this is not large, it is so distributed as best to subserve the purposes of vegetable growth. No moisture is lost in superfluous spring and autumn rains, or in the cold and non-producing part of the year, the precipitation, which in winter is less than 2 inches, increasing to about 12 for the summer. To the season of vegetable growth belong 70 per cent. of the yearly measures of heat, 76 per cent. of the rainfall, and 76 per cent. of the atmospheric humidity. The prevailing winds are from the south or south-east. In 1880 rain or snow fell on 150 days, and in 1881 on 167. It is evident that the causes which mitigate the actual severity of the climate as felt, which produce so large a number of clear days, and which forbid the continued presence of a large amount of moisture in the atmosphere, are those which render a climate healthful in the highest degree. Minnesota has been for many years a favourite resort for invalids. The curative properties of its climate are especially marked in the case of pulmonary complaints.

Agriculture.—The leading industry of the State is agriculture. The character of the surface soil varies in different parts of the State with the character of the underlying strata. The fertile land comprises about three-fourths of the entire area of the State. The drift soil proper of the south and centre, including the Minnesota valley and the greater part of that of the Mississippi, contains silica and calcareous matter, and is interspersed with alluvial river bottoms. The limestone soil, in which there is a large calcareous element, lies chiefly on the western slope of the Mississippi. The Red River valley consists of an argillaceous mould, rich in organic deposits. Around Lake Superior, wherever arable land is to be found, it is marked by a rich trap soil. North of the central fertile area, and in the neighbourhood of the sources of the Mississippi, is much swampy land, susceptible of easy drainage, with a large tract of sand and other drift detritus, unfavourable to production. Maize and potatoes flourish, and the uplands, which support hardwood ridges, are suited to general agriculture. To the extreme north the surface, while indicating mineral wealth, is utterly unfit, except in occasional isolated areas, for purposes of tillage.

Wheat has hitherto been the staple product of the State. Soil and climate are such as to ensure a large average yield, while the superior quality of the grain has given it a wide reputation. The other cereals are also cultivated with success. The tendency to diversify agriculture, especially in the southern part of the State, has been stimulated by several partial failures of the wheat crop, the locust invasions, and the competition of the farther north-west.

The area of the State includes 39,791,265 acres surveyed, 10,968,575 acres not surveyed, and 2,700,000 acres of lake surface. The total sales of public and railroad lands in 1879 and 1880 were not far from 4,000,000 acres. It is estimated that the aggregate of lands yet undisposed of, three-fourths of which may be profitably cultivated, is nearly 20,000,000 acres, exclusive of the lands belonging to the State. White Earth Indian reservation has thirty-six townships of prairie and timber land; and Red Lake reservation contains 3,200,000 acres.

Forestry.—A special census bulletin estimates the amount of merchantable white pine standing, May 31, 1880, as amounting in all to 6,100,000,000 feet. The entire cut for the census year 1880 was 540,997,000 feet. Of hardwood forest 3,840,000 acres remain, capable of yielding 57,600,000 cords of wood.

Every encouragement is afforded, both by the railway corporations and the State, to tree-planting on the prairies. A quarter section is given to any one who will plant and keep in good condition 40 acres of timber for eight years. In 1880 there were planted 25,331 acres of trees, exclusive of those bordering highways and the windbreaks along the railroad lines.

Manufactures.—The manufactures of Minnesota are yet in their infancy. The abundant water-power of the State, its proximity to the coal-fields of Iowa, its superior transportation facilities, and the large demand for manufactured commodities are, however, rapidly developing this branch of industry. The most important industries are the manufacture of flour and that of lumber. The former naturally established itself in a State of immense wheat yield and abundant water-power. It received its greatest stimulus from the invention and adoption of the middlings purifying process, which produces the highest grade of flour, and to which the hard spring wheat of Minnesota is especially adapted. Among other manufacturing industries actively prosecuted are the making of brick, pottery, stoneware, and agricultural implements, and also meat-packing.

Commerce.—The geographical position of Minnesota gives it extensive commercial interests. Two continental waterways terminate within the State. The Mississippi affords continuous navigation to European ports during eight months of the year. From Duluth numerous lines of vessels traverse the chain of great lakes, and transport the products of the west to the eastern seaboard. Three great transcontinental railway lines are connected more or less directly with the railroad system of the State. Twelve lines of railway from every part of Minnesota converge at the contiguous cities of St Paul and Minneapolis, and three great trunk lines from these centres to Chicago secure the advantages of a lively competition.

Education.—The common school system is supported by land grants, a local tax, and a State tax. The superintendent of instruction is appointed by the governor. County superintendents are chosen by popular vote. Common school districts have boards of three trustees each. Six directors are appointed for independent districts. The permanent fund in 1881 was $4,850,000, and the current fund $260,835. The State university, located at Minneapolis, is governed by a board of regents, consisting of the governor of the State, the superintendent of public instruction, the president of the university, and six others; both sexes are admitted, and tuition is free. The State supports three normal schools. Forty-two academies and six colleges are sustained by denominational or private enterprise.

Administration.—The departments of Government are, as in all the States, the legislative, the executive, and the judicial. The State contains seventy-eight counties, of which some are still subject to change of boundary. From these are elected by districts forty-seven senators and one hundred and three members of the House of Representatives. The State officers are a governor, lieutenant-governor, secretary of state, treasurer, and attorney-general, all elected by the people. The term of office is two years.

The governor has power to veto separate items of a money bill. The judiciary is elective, and the term of office seven years. The State requirements for citizenship are residence in the United States one year, in the State four months, and in the election district ten days preceding an election. Women are allowed to vote for school officers and upon questions relating to the management of schools, and are also eligible to such offices. No county can contain more than 400 square miles. The legislature meets biennially. Extra sessions may be called, but no session can exceed sixty days in length. Under the last apportionment the State is entitled to five representatives in the national Congress.

The annual valuation of property for 1882, as equalized by the State board, gives the personal property as $79,219,445, the real estate $242,938,170. This represents a total actual value of not far from $750,000,000.

While Minnesota was still a Territory, but after it had adopted a State constitution, an amendment was added to the constitution authorizing the issue of a large amount of bonds in aid of railway construction. Shortly afterwards, the companies having failed to fulfil their contracts and defaulted payment, the State foreclosed its mortgage on the lands, franchises, &c., of the roads, and turned them over to other companies. By another amendment to the constitution, the payment of the bonds was made contingent upon the result of a popular vote. Several proposals having failed to receive this sanction, the necessity for it was removed in 1881 by a decision of the supreme court, declaring the amendment unconstitutional. The legislature immediately met, accepted a plan of settlement proposed by the bondholders themselves, and over $4,000,000 worth of new bonds were issued in exchange for the old. For the payment of the principal and interest of these the people have voted (November 1882) to set aside as a sinking fund the proceeds of 500,000 acres of land belonging to the State internal improvement fund, the deficit to be paid out of the tax on railroad earnings. These bonds include all the State debt except about $200,000. A tax of 3 per cent. imposed on the gross earnings of all railroads within the State will soon meet all expenses except provision for educational, penal, and charitable institutions.

Population.—The population of the State was 6077 at the census of 1850, 172,023 in 1860, 439,706 in 1870, and 780,773 (419,149 males and 361,624 females) in 1880. According to the last census 299,800 whites had been born in the State; and of the 267,676 foreign-born inhabitants of the State 107,770 came from Scandinavian countries and 68,277 from the United Kingdom and the British colonies, while 77,505 acknowledge the German as their native tongue. The increase of population in the State for the last decade of years alone was 75 per cent. The most important cities are St Paul, the capital, and Minneapolis, with 41,473 and 46,887 inhabitants respectively in 1880; Winona had 10,208 and Stillwater 9055.

History.—Missionary efforts and the trading spirit first induced white men to venture as far into the unexplored north-west as the boundaries of what is now the State of Minnesota. The earliest accounts of its natural features and native tribes appear in the Jesuit writings. The "Relations" of 1670–71 allude to the Sioux or Dakotas. In 1678 a company was formed for trading with this tribe. Du Luth was leader of this expedition, and later on went from Lake Superior to the Mississippi by canoe. But the first published account is that of Louis Hennepin, a Recollect monk, who, in 1680, visited the falls of St Anthony, and gave them their name, from that of his patron saint. For a century the only visitants of the wild region were a few missionaries, and a number of fur traders who found the profit of the journey to more than counterbalance its perils and hardships. To the latter class belong Perrot, who reached the Mississippi by way of the Fox and Wisconsin in 1684, and founded at Lake Pepin the first trading post in the State, and Le Sueur, a Canadian, who ascended the great river from its mouth, and established another post above Lake Pepin. Captain John Carver, the explorer of the country of the upper Mississippi, visited the falls of St Anthony in 1766, being the first British traveller who reached the spot. On March 20, 1804, Upper Louisiana was organized, consisting of Arkansas, Missouri, Iowa, and a large portion of Minnesota. From this time onwards the progress of exploration was rapid, and settlement followed in its train. The first really extensive exploration of any large part of what is now Minnesota was made between 1817 and 1823, by Major S. H. Long, of the United States engineer corps, in command of a Government expedition. About the same time the Red River received its first visitant. Thomas Douglas, earl of Selkirk, an Englishman of eccentric character, went, in 1817, to what is now Winnipeg, by way of York river. Having been struck with the agricultural possibilities of the region about the Red River of the North, he induced a colony of Swiss farmers to settle there. These were disappointed in the country, and unused to the severity of the climate, so that they finally removed to the vicinity of St Paul and contributed to the earliest development of the agricultural industry of the State. In 1821 Colonel Snelling built, at the junction of the Minnesota and Mississippi rivers, a stronghold which he named Fort St Anthony. The name was changed to Fort Snelling in his honour, in 1824, and the fort is still an important post as a base of supplies for the newer north-west. The first steamboat made its appearance at the head of navigation in 1823. The settlement of St Paul, one of the oldest towns as well as the capital, is commonly dated from 1846, at which time there were a few shanties on its site. Population now began to arrive in constantly increasing numbers, and on March 3, 1849, a bill passed Congress for organizing the Territory. It was proposed at one time to name it Itasca, but the name Minnesota, meaning, "sky-tinted water," and originally applied to the river bearing that title, was finally retained. The western boundary of the territory was fixed at the Missouri river. The population was but 4057, the largest town had but a few hundred inhabitants, and a large part of the soil of the State still belonged to the Indians. But progress now began in earnest. A constitution was adopted in 1857, and on May 11, 1858, Minnesota was admitted as a State, with a population, according to the last Territorial census, of 150,037.

One of the first acts of the new State was the issue of the railroad bonds noticed above. Soon after came the civil war. Within two months of Lincoln's first call for troops the first Minnesota regiment, over one thousand strong, was mustered into service. By August of 1862 ten regiments had been called for and furnished. In all, the State supplied to the armies of the Union 25,052 men, or about one-seventh of its entire population at the outbreak of the war.

In the meantime there occurred, in 1862, the horrible outbreak known as the Sioux massacre. Settlements were cut off, isolated settlers murdered, and even a strong post like Fort Ridgely was attacked. The outbreak spread over a large portion of the State; several severe engagements were fought; and it was not until the State had a thoroughly equipped military force ready for the campaign that the Indians begun to flee or to give themselves up. By this time over 700 persons had been murdered, 200, chiefly women, taken captive; eighteen counties were ravaged, and 30,000 people were homeless. The property loss was not less than $3,000,000.

During these local and national disturbances the material prosperity of the State was unabated. Notwithstanding the heavy cost of the civil war and the Sioux massacre, the census of 1865 showed a population of 250,099. Railroad construction began to be energetically carried forward; in 1870 329 miles were made and 1096 miles were in operation; a road to Lake Superior was completed, and the Northern Pacific was fairly under way. In 1873–76, and to some extent in 1877, successive visitations of locusts destroyed the crops of the south-western counties. The sufferers were relieved by the State, and no repetition of the scourge has since been experienced. (J. G. P.)

MINNOW (*Leuciscus phoxinus* or *Phoxinus lævis*) is the smallest British Cyprinoid, readily distinguished by its very small scales. It is abundant in rivers, brooks, and lakes, always swimming in schools, and shifting its ground in search of food, which consists of every kind of vegetable and animal substance. It ranges from southern Europe to Scandinavia, and from Ireland into north-eastern Asia; in the Alps it attains to a higher altitude than any other Cyprinoid, viz., to nearly 8000 feet. Its usual size varies between 2 and 3 inches; but in suitable localities, especially in Germany, it is known to reach a length of from 4 to 5 inches. The colours vary with age and season; a series of dark spots or cross-bands along the sides is always present, but the males assume in summer a nuptial dress of scarlet or purple on the lower parts of the head and body. The minnow is used as bait; it can also be introduced with facility and with great advantage into ponds in which there is otherwise a scarcity of food for more valuable fishes, such as trout, perch, and pike.

MINO DI GIOVANNI (1431–1486), called DA FIESOLE, was born at Poppi in the Casentino in 1431. He had property at Fiesole, whence his usual name. Vasari's account of him is very inaccurate and full of contradictions. Mino was a friend and fellow-worker both with D. da Settignano and Matteo Civitale, all three being about the same age. There is considerable similarity in their works, showing mutual influence. Mino's sculpture is remarkable for its gem-like finish and extreme delicacy of detail, as well as for its spirituality and strong devotional feeling. No other sculptor portrayed the virginal purity of the Madonna or the soft infant beauty of the Divine Child with greater tenderness and refinement. Of Mino's earlier works, the finest are in the duomo of Fiesole, the altarpiece

and tomb of Bishop Salutati, executed about 1464. In the Badia of Florence are some of Mino's most important sculptures—an altarpiece, and the tombs of Bernardo Giugni, 1466, and the Margrave Hugo, 1481—all sculptured in white marble, with beautiful life-sized recumbent effigies and attendant angels. The pulpit in Prato cathedral, finished in 1473, is very delicately sculptured, with bas-reliefs of great minuteness, but somewhat weakly designed. Soon after the completion of this work Mino paid a visit of some years to Rome, where he executed several fine pieces of sculpture, such as the tomb of Pope Paul II. (now in the crypt of St Peter's), the tomb of Francesco Tornabuoni in S. Maria Sopra Minerva, and a beautiful little marble tabernacle for the holy oils in S. Maria in Trastevere. There can be little doubt that he was also the sculptor of several of the very lovely monuments in S. Maria del Popolo, especially those in the sacristy of Bishop Gomiel and Archbishop Rocca, 1482, and the marble reredos, also in the sacristy, given by Pope Alexander VI. Some of Mino's portrait busts and delicate profile bas-reliefs are preserved in the Bargello at Florence; they are full of life and expression, though without the extreme realism of Verrocchio and other sculptors of his time. He died in 1486.

See Vasari, Milanesi's ed., 1878–82; Perkins, *Italian Sculptors*; Winckelmann and D'Agincourt, *Storia della Scultura*, 1813.

MINOR. See INFANT.

MINORCA. See BALEARIC ISLANDS.

MINORITES. See FRANCISCANS.

MINOS, a legendary king of Crete, in whom both historical and religious elements are united. The historical element lies in the fact that an early civilization and maritime power had its seat in Crete. The Phœnician intercourse played a great part in developing this island state, and Minos is sometimes called a Phœnician. The name Minoa is often found where Phœnician influence was strongest, *e.g.*, at Megara. The laws and constitution which existed from a very early time in Crete were attributed to Minos, to whom they were revealed by Zeus. After his death he became the judge of the dead; he is one of the forms assumed by the old conception of the first man, who is after death king and god among the dead. It is therefore highly probable that the name Minos is the Greek form of the original *Manva*, *i.e.*, "endowed with thinking," which is seen in the Hindu Manu and the Germanic Mann. As in all other heroized forms of the god of the dead, there is both a terrible and a wise and beneficent side in the character of Minos. Cretan legends described him as the wild huntsman of the forests and mountains, the lover of the nymphs, though his love means death to them. His death is localized in the far west, in the land of sunset; his grave was shown at Camicus near Agrigentum, attached to a temple of Aphrodite. He pursued Dædalus thither, and the daughters of Cocalus, the king of Agrigentum, killed him by pouring boiling water over him in the bath, an obvious myth of the sun dying in the sea. Minos, the god of the dead, is, according to the usual rule, the sun-god, who goes to illumine the dead when he dies on the earth. His wife is Pasiphae, the moon-goddess, who had an oracle by dreams at Thalamæ in Laconia. The union of the sun and the moon, the bull and the cow, gave rise to many quaint and ugly legends: Pasiphae loved the bull of Minos, was aided by the stratagem of Dædalus, and gave birth to the Minotaur, half bull and half man. The Minotaur is one of those monstrous forms which were suggested to the Greek fancy by the quaint animals common in Oriental art. It was shut up in the LABYRINTH (*q.v.*), which was constructed by the skilled artist Dædalus. Now a son of Minos named Androgeus had been killed by the Athenians, and Minos as a punishment required that seven youths and seven maidens should be sent every ninth year and given up to the Minotaur to be devoured. When this sacrifice took place for the third time Theseus came as one of the hostages, and slew the Minotaur with the help of Ariadne. Throughout these legends we see the close relation of Minos to the Phœnician sun-god Melkarth, and perceive the way in which different places where Phœnician influence can be traced, Athens, Sicily, &c., are brought together in religious myths.

MINOTAUR. See MINOS.

MINSK, a western government of Russia, is bounded by Vilna, Vitebsk, and Moghileff on the N. and E., and by Tchernigoff, Kieff, Volhynia, and Grodno on the S. and W., and has an area of 35,175 square miles. The surface is undulating and hilly in the north-west, where a narrow plateau and a range of hills of the Tertiary formation runs to the north-east, separating the basin of the Niemen, which flows into the Baltic, from that of the Dnieper, which sends its waters into the Black Sea. The range, which averages from 800 to 1000 feet, culminates in Lysaya Gora (1129 feet). The remainder of the province is flat, 450 to 650 feet above the sea-level, covered with sands and clays of the glacial and post-glacial periods. Two broad shallow depressions, drained by the Berezina and the Pripet, cross the province from north to south and from west to east; and these, as well as the triangular space between them, are covered with immense marshes (often occupying 200 to 600 square miles), numberless ponds and small lakes, peat-bogs, downs, and moving sands, as well as with dense forests. This country, and especially its south-western part, is usually known under the name of Polyesie ("The Woods"). Altogether, marshes take up 15 per cent. and marshy forests no less than 55 per cent. of the entire area of the province (60 to 71 per cent. in several districts). The forests, however, consist of full-grown trees in the higher districts of the north-west only, those which occupy the marshy ground consisting of small and stunted pine, birch, and aspen. The climate of the Polyesie is harsh and extremely unhealthy; malarias and an endemic disease of the bulbs of the hair (*koltun*, *plica Polonica*) are the plagues of these tracts, the evil being intensified by the dreadful poverty of the population. Communication is very difficult. The railway from Poland to Moscow has, so far as Minsk is concerned, taken advantage of the plateau above mentioned; but still it has to cross the broad marshy depression of the Berezina. A successful attempt was recently made to drain the marshes of the Polyesie by a system of canals, and more than 4,500,000 acres have thus been rendered suitable for pasture and agriculture. Two great tributaries of the Dnieper, the Berezina and the Pripet, both navigable, with numberless subtributaries, many of which are also navigable, are the natural outlets for the marshes of the province. The Dnieper flows along its south-eastern border for 160 miles, and the Niemen on the north-western for 130 miles. The affluents of the Baltic, the Duna (Dwina), and the Vistula are connected by three canals with tributaries of the Dnieper. The population of the province (1,183,200 in 1873) may be estimated at about 1,350,000, mostly White Russians (67 per cent.); there are also Poles (about 11 per cent.), especially in the western districts, Jews (more than 10 per cent.), Little Russians (5 per cent.), and Russians (2 per cent.). About 70,000 are considered to be Lithuanians; there are also 4000 Tartars, whose presence can be traced to the raids of their ancestors on Lithuania in the 13th century, and about 2000 German agriculturists who settled in last century

The chief occupation of the inhabitants is agriculture, which is, however, very unproductive in the lowlands; in the Polyesie the peasants rarely have pure bread to eat. Only 23·8 per cent. of the

area is under crops, the average yield being 1,600,000 quarters of corn and 1,170,000 quarters of potatoes. Cattle-breeding is very imperfectly developed, the meadows being marshy throughout the lowlands. Hunting and bee-keeping are sources of income in the Polyesie, and fishing gives occupation to about twenty thousand persons. The chief source of income for the inhabitants of the lowlands is the timber trade. Timber is floated down the rivers, and tar, pitch, various products of bark, potash, charcoal, and numerous sorts of timber-ware (wooden dishes, &c.) are manufactured in villages to a great extent; and shipbuilding is carried on along the Dnieper, Pripet, and Niemen. Shipping is also an important source of income, owing to the traffic on the canals and rivers of the province. In 1877 560 boats and 1120 rafts with 170,000 cwts. of cargo left the banks of the Berezina and Pripet; and the traffic on the Dnieper and Niemen was nearly as great. The industrial arts are almost entirely undeveloped. There are, however, several distilleries and tanneries; and woollen-stuffs, candles, tobacco, and sugar are manufactured to a limited extent. Corn is exported from the western districts, but imported to the same amount into the southern parts; the chief export trade is in produce of forest industries. The province is crossed by two important railways, one of which connects Poland with Moscow, and the other Libau and Vilna with the provinces of Little-Russia; the great highway from Warsaw to Moscow crosses the province in the south, and its passage through the Berezina is protected by the first-class fortress of Bobruisk. Minsk is divided into nine districts, of which the capitals are—Minsk (43,500 inhabitants), Bobruisk (26,850), Borisoff (5650), close by the place where Napoleon I. crossed the Berezina on his retreat from Moscow, Igumen (2200), Mozyr (4200), Novogrodek (9000), Pinsk (18,000), Ryechitsa (4300), and Slutsk (17,200). The province is well provided with secondary schools, but primary education, especially in the Polyesie, is in a very backward state.

The country now occupied by the province of Minsk was, as far as historical records extend, an abode of Slavonians. That portion of it which was occupied by the Krivichi became part of the Polotsk principality and so of "White Russia"; the other portion, occupied by the Dregovichi and Drevlans, became part of the "Black Russia"; whilst the south-western portion of it was occupied by Yatvyags or Lithuanians. During the 12th, 13th, and 14th centuries it was divided among several principalities, which were incorporated with the great principality of Lithuania, and later were annexed to Poland. Russia took possession of this country in 1793. In 1812 it was invaded by the army of Napoleon I.

MINSK, the capital of the above province, is situated on the Svisloch, a tributary of the Berezina, at the junction of the Moscow and Warsaw and the Libau and Kharkoff railways, 465 miles by rail west from Moscow. It has 43,500 inhabitants, of whom one-third are Jews of the poorest class; the others are White Russians, Poles, and Tartars (about 700). The manufactures are few and insignificant. Since the introduction of railways the commercial importance of the place, which formerly was slight, has begun to increase.

Minsk is mentioned in Russian annals in the 11th century under the name of Myen'sk or Menesk. In 1066 and 1096 it was devastated, first by Izyaslav and afterwards by Vladimir. It changed rulers many times until the 13th century, when it became a Lithuanian fief. In the 15th century it became part of Poland, but as late as 1505 it was ravaged by Tartars, and in 1508 by Russians. In the 18th century it was taken several times by Swedes and Russians. Russia annexed it in 1793. Napoleon I. took it in 1812.

MINSTREL. The "minstrels," according to Bishop Percy, "were an order of men in the Middle Ages who united the arts of poetry and music, and sang verses to the harp of their own composing, who appear to have accompanied their songs with mimicry and action, and to have practised such various means of diverting as were much admired in those rude times, and supplied the want of more refined entertainments." This conception of the "minstrel" has been generally accepted in England ever since Percy published his *Reliques of Ancient Poetry*, which he gave to the world as the products of the genius of these anonymous popular poets and harpers. The name has been fixed in the language by the usage of romantic poets and novelists; Scott's "last minstrel" and Moore's "minstrel boy" were minstrels in Percy's sense of the word. The imagination was fascinated by this romantic figure, and the laborious and soured antiquary Ritson argued in vain that nobody before Bishop Percy had ever applied the word minstrel to such an order of men, that no such order of men ever did exist in mediæval England, and that the historical English "minstrels," so-called, were a much less gifted and respectable class, being really instrumental musicians, either retainers or strollers.

The dispute between Ritson and Percy was partly a dispute about a word, and partly a dispute about historical facts; and there can be little doubt that Ritson was substantially right in both respects. The romantic bishop transferred to the mediæval English minstrel the social status and brilliant gifts of the Anglo-Saxon *gleoman* or *scôp*, and the French *troubadour* in the flourishing period of Provençal poetry. That the gleemen sang to the harp verses of their own composing, that some of them travelled from court to court as honoured guests, while others were important attached court officials, and all received costly presents, is a well attested historical fact. The household bard at Heorot in the poem of *Beowulf*, a man who bore many things in mind and found skilfully linked words to express them, was one of King Hrothgar's thanes; the gleeman of the *Traveller's Song* had visited all the tribal chiefs of Europe, and received many precious gifts, rings and bracelets of gold. The incidents in these poems may not be historic, but they furnish indubitable testimony to the social position of the gleeman in those days; a successful gleeman was as much honoured as a modern poet-laureate, and as richly rewarded as a fashionable *prima donna*. Further, the strolling gleeman of a humbler class seems to have been respected as a non-combatant; this much we may infer from the stories about Alfred and Anlaff having penetrated an enemy's camp in the disguise of gleemen, whether these stories are true or not, for otherwise they would not have been invented. The position of poets and singers in Provence from the 11th to the 13th century is still clearer. The classification of them by King Alphonso of Castile in 1273, by which time honourable designations were getting mixed, may help to determine the exact position of the English "minstrel." There was first the lowest class, the *bufos*, who strolled among the common people, singing ribald songs, playing on instruments, showing feats of skill and strength, exhibiting learned dogs and goats, and so forth; then the *joglars* or *joculatores*, who played, sang, recited, conjured, men of versatile powers of entertainment, who performed at the houses of the nobility, and were liberally remunerated; then the *trobadors*, or *inventores*, whose distinction it was to compose verses, whether or not they had sufficient executive faculty to sing or recite them.

If we compare these distinctions with Percy's definition of the minstrel, we see that his minstrel would have corresponded with the *joglar*, who also wrote his own songs and recitations. Now in the palmy days of Provençal song there were many professional joglars, such as Arnaut Daniel or Perdigo, who stood high among the most brilliant troubadours, and visited on terms of social equality with nobles and princes. But long before English became the court language the fashion had disappeared, and a new division of functions had been developed. In Chaucer's time the poet of society no longer sang his verses to harp or fiddle, or amused his patrons with feats of legerdemain; the king's *gestour* (teller of *gestes*) discharged the professional duty of amusing with witty stories; and the social position of the *joglar* had very much sunk. Ritson was perfectly right in saying that no English poet of any social position was a professional reciter to the harp of verses of his own composing. The Provençal joglar, travelling from court to court, combined our modern functions of poet, society journalist, entertainer, and musician. But about the time when the word "minstrel" came to be applied to him the English joglar was rapidly sinking or had already sunk to the social position of the modern strolling mountebank, travelling showman, or music-hall singer. And the

word minstrel had had a separate history before it became synonymous (as in the *Catholicon Anglicum* of 1483) with *gesticulator, histrio, joculator*, and other names for strolling entertainers. Derived from the Low Latin *ministralis*, it was originally applied to those retainers whose business it was to play upon musical instruments for the entertainment of their lords. In Chaucer's *Squire's Tale*, the "minstralles" play before King Cambuscan as he dines in state "biforn him at the bord deliciously," and the "loude minstralcye" precedes him when he rises and withdraws to the ornamented chamber,

> Ther as they sownen diuerse instrumentz,
> That it is lyk an heuen for to here.

But even in Chaucer's time there were less respectable musicians than those of the king's household—strolling musicians, players on trumpets, clarions, taborets, lutes, rebecks, fiddles, and other instruments. These also were known by the generic name of minstrels, whether because many of them had learnt their art in noble households before they took to a vagabond life, or because the more respectable of them affected to be in the service or under the patronage of powerful nobles, as later on companies of strolling players figured as the "servants" of distinguished patrons. All the allusions to minstrels in literature from Langland's time to Spenser's point to them as strolling musicians. Some of them may have sung to the harp verses of their own composing, and some of them may have composed some of the ballads that now charm us with their fresh and simple art; but the profession of the "minstrel," properly so-called, was much less romantic than Bishop Percy painted it. It was not merely "the bigots of the iron time" that "called their harmless art a crime"; in a repressive Act passed by Henry IV. they appear with "westours, rymours, et autres vacabondes" among the turbulent elements of the community.

In a passage in Malory's *Morte Darthur*, the word minstrel is applied to a personage who comes much nearer the ideal of the Provençal *joglar*. When Sir Dinadan wished to infuriate King Mark, he composed a satirical song, and gave it to Elyot a harper to sing through the country, Tristram guaranteeing him against the consequences. When King Mark took him to task for this, the harper's answer was, "Wit you well I am a minstrel, and I must do as I am commanded of these lords that I bear the arms of." And because he was a minstrel King Mark allowed him to go unharmed. The service done by Elyot the harper in the old romance is a good illustration of the political function of the itinerant mediæval *joculator*; but even he did not sing verses of his own composing, and he was not a "minstrel" in the sense in which the word was used by romantic poets after the publication of Percy's *Reliques*. (W. M.)

MINT. The mint is the place where the coinage of a country is manufactured, and whence it is issued by sovereign authority, under special conditions and regulations. The privilege of coining has in all ages and countries belonged to the sovereign, and has, in England at least, been rarely delegated to any subject, and in any case in a restricted form, the crown always reserving the right of determining the standard, denomination, and design of the coins.

At a very early stage of civilization it was found necessary to have some definite medium of exchange, in order to avoid the great inconvenience arising from the system of payment in kind, which was the primitive and natural method. It was not long before metal came to be used as such a medium, probably from its durability and portability, and in the case of gold and silver on account of their intrinsic value. The less liable the value of a metal is to change the better is it suited for a standard of value.

Though historians assure us that metals were found in Britain at a very early period, there does not appear to be any evidence that the mines were worked until considerably later than the time at which the use of metal as a medium of exchange was introduced. It is probable therefore that the metals for exchange were imported into Britain long before the native mines were developed.

The metals chiefly used were silver and brass, which were at first simply exchanged by weight for commodities of all kinds. As commercial transactions became more numerous and more complicated, this system of payment grew troublesome, and it was found convenient to divide the mass of metal into small parts, which soon took the form of rough coins. But the principle of payment by weight was retained through many centuries, and is perpetuated, though in name only, in the word "pound."

Records of attempts to organize the coinage of England are found as far back as the Anglo-Saxon period, and it is known that on the dissolution of the Heptarchy the mints were regulated by laws framed in the witenagemot. The first monarch who appears to have dealt successfully with the organization of the coinage was Athelstan, who framed laws for the regulation of the mints, and appointed officers whose titles and duties are then first recorded. The only officers connected with the coinage of whom mention is found before this time are the "moneyers," who appear to have been alone responsible for the manufacture of the coin; but it is probable that even then there existed some officer who had authority over them. In early Saxon and Norman times the number of moneyers was considerable, mints being established in almost every important town, as might be expected at a period when communication between distant places was extremely difficult. They appear to have been the officers who actually performed the work of making the coin, the mint master in later times contracting with them, at a high rate, for the work. They were responsible for the purity and perfection of the coins produced, as appears from the fact that it was they who were punished (as traitors) in the case of any deficiency in weight or fineness. They had prescriptive rights in the coinage, and in modern times (even so late as 1850) claimed to have corporate privileges; but it is clear, on the authority of Ruding, that they never were a "corporation" separate from other officers of the mint.[1] The number of mints was greatly reduced after the Norman Conquest, but continued to be considerable until the reign of Richard I., when the work of coining for the whole kingdom was concentrated in the mint in the Tower of London. Only one provincial mint (Winchester) remained till a later date.

An important reorganization of the coinage took place in 1325 under Edward II., the regulations then framed for the manufacture and issue of the coins forming the basis of those still in force. The principal officers under these regulations were—master, warden, comptroller, king's assay master, king's clerks, and cuneator. The office of cuneator was one of great importance at a time when there existed a multiplicity of mints, since he had the sole charge of all the dies used not only at the mint in the Tower of London but also in the provinces. He chose the engravers and presented them to the barons of the exchequer in order that they might take the oath of fidelity; he superintended their work, and was generally answerable for the perfection of the dies before they were issued for use in the various mints of the country. The office, which was hereditary, ceased to exist when the provincial mints were suppressed. In its place was instituted the office of clerk of the irons,

[1] Among the special privileges which they undoubtedly enjoyed was exemption from local taxation, as appears in a writ of Henry III., which commands the mayor of London not to disturb them "by exacting tallages contrary to their privileges." Sometimes also houses were allowed to them rent free.

whose functions were more limited, and were not hereditary. This office was only recently abolished.

In the Middle Ages an important duty devolving on the officers of the mint was the collection of the seigniorage which was levied on the coining of money, not only for the purpose of covering the expenses of minting, but also as a source of revenue to the crown which the sovereign claimed by virtue of his prerogative. In former times the collection of the seigniorage was entrusted to the warden, who also superintended the manufacture of the coins, so far as to ensure the proper relations between the moneyers on the one hand and the state on the other. He does not appear, however, to have had any responsibility with regard to the fineness and weight of the coins.

The king's assay master was specially charged with all matters relating to the accuracy of the standard. The officer next in rank to him was the comptroller, who presented annually to the barons of the exchequer a report of all the gold and silver money struck in the kingdom during the year. These reports, which were always written upon parchment, constitute the chief mint records. The king's clerk exercised a general superintendence and kept an account of all the mint transactions. As the work of the mint became more extensive and more complicated, other officers were added such as the surveyor of the meltings, surveyor of the money presses, and many others.

The present arrangements with regard to the officers of the mint were made in 1870, when several important changes took place in the mint establishment. Up to that time there had been two controlling officers,—the master, who in some instances was selected on account of distinguished scientific attainments (as in the cases of Sir John Herschel and Professor Graham), and the deputy master and comptroller. A careful inquiry, however, having led to the conclusion that the control of the mint might with advantage be concentrated in the hands of a single officer of experience in the conduct of public business, it was decided, on the death of Professor Graham, to entrust the actual administration of the department to the deputy master,—the office and title of master of the mint being held by the chancellor of the exchequer for the time being, without salary. At the same time the services of a scientific officer were secured, by the appointment of a chemist of the mint. The coining and die department and the melting department were united under the name of the operative department, and placed under a single superintendent. The first deputy master appointed under the new regulations was the Hon. C. W. Fremantle, C.B., to whom the public are indebted for a series of *Annual Reports* which have given a new and increased interest to the subject of the coinage, and may be said to constitute in themselves a mint literature.

The actual operations of coining in early times were few in number and simple in character. The metals forming the alloy were melted together in the proportion necessary to bring them to the required standard, and the alloy thus obtained was cast into bars, which were reduced by hammering to the requisite thickness. They were then cut with shears into pieces more or less regular in size and form, roughly annealed, and finally impressed with the prescribed device by a blow with a hammer.

The last-named appears to have been the only part of the process which was performed with any great amount of care. The blank piece was placed by the hand upon a die fixed into a block of wood having a large heavy base to resist the oscillation caused by the blow; the die on which was engraved the device for the reverse of the coin was then placed upon the upper side of the blank and held by means of a holder, round which was placed a roll of lead to protect the hand of the operator while heavy blows were struck with a hammer by an assistant workman. One of the earliest improvements in coining was the introduction of a tool in shape resembling a pair of tongs, the two dies being placed one at the extremity of each leg. This avoided the necessity of readjusting the dies between successive strokes of the hammer, and ensured greater accuracy in the impression. It was long before the system of coining by hand was superseded by the coining press, or mill, which, even after its first introduction, was only very slowly adopted. Several attempts were made to introduce machinery for coining before it was brought into active use, the objection to it being its great expense. The mill and screw were finally introduced into the mint under Charles II., when many improvements were also made in the preliminary operations. Steam-power was first applied in 1810, when the vacuum screw-press was introduced. In 1839 Uhlhorn invented the lever-press, which still remains in use.

The subject of the design on coins, besides being interesting both from an artistic and an historical point of view, becomes very important when it is remembered that it is the impression of the coin with the authorized device which makes it legally current. The artistic merits of the design of the early Greek coins are well known, and prove that the dies from which the coins were struck must have been engraved with much skill and care. The form of the coins before being stamped was at first merely that of natural rounded nuggets of gold, or of the silver-gold alloy known as *electrum*. Such coined nuggets of gold are still to be found among the hill tribes of India. Simple nuggets were afterwards replaced by roughly-fashioned masses like half bullets, a form which rendered it easy to impart high relief to the obverse and comparatively low relief to the reverse of the coins. The early British coins [1] had for their prototype the gold "stater" of Philip of Macedon, but the design of this beautifully finished coin was so roughly imitated by a succession of British copyists that ultimately the wreath round the head of the monarch alone survived, and that in a scarcely recognizable form. It is not only in the early British coins that the influence of classical art may be seen, for it is very evident in some of the present day, the most notable instances being the reverse of the bronze coinage, and the beautiful design of St George and the dragon by Pistrucci, which is still used as an alternative design for the sovereign. It has been ascertained that the impressions on the reverse of very early Greek coins were produced by the rough surface of the anvil or the nail head on which they were placed, while the obverse was struck with the die. A little later the device on the reverse of the coins was obtained by placing the blank piece on small points of metal arranged in geometrical forms which caused corresponding indentations on the coins when struck with the hammer. The beauty and accuracy of design on coins gradually increased as art and manual skill developed, and probably culminated at the period of the Renaissance.

Although it has been the custom since the time of the Saxons to stamp coins with the head of the reigning monarch, it does not appear that any attempt at actual portraiture was made in England until the reign of Henry VII., who, "about the eighteenth or nineteenth year of his reign, did make a great alteration in the form of his coin, upon which his head was now represented in profile, and with a good resemblance of his other pictures." [2] Since then much care seems to have been taken to stamp the coins with a true likeness of the monarch. In most cases the heads bear a striking resemblance to the portraits drawn by the great artists of the respective periods, and were, indeed, generally designed by artists of eminence. Some of the Milan coinage of Louis XII. is said to have been

[1] See Evans, *Coins of the Ancient Britons.*
[2] See Martin Folkes, *Tables of English Silver and Gold Coins.*

Denomination of Coin.	Standard Weight.		Least Current Weight.		Standard Fineness.	Remedy Allowance.		
	Imperial Weight. Grains.	Metric Weight. Grammes.	Imperial Weight. Grains.	Metric Weight. Grammes.		Weight per Piece. Imperial Grains.	Weight per Piece. Metric Grammes.	Millesimal Fineness.
Gold—								
Five pound	616·37239	39·94028	612·50000	39·63935	11/12 fine gold, 1/12 alloy; or millesimal fineness 916·66.	1·00000	0·06479	0·002
Two pound	246·54895	15·97611	245·00000	15·87574		0·40000	0·02592	
Sovereign	123·27447	7·98805	122·50000	7·93787		0·20000	0·01296	
Half-sovereign	61·63723	3·99402	61·12500	3·96083		0·10000	0·00648	
Silver—								
Crown	436·36363	28·27590	...	...	37/40 fine silver, 3/40 alloy; or millesimal fineness 925.	1·81818	0·11781	0·004
Half-crown	218·18181	14·13795	...	...		0·90909	0·05890	
Florin	174·54545	11·31036	...	...		0·72727	0·04712	
Shilling	87·27272	5·65518	...	...		0·36363	0·02356	
Sixpence	43·63636	2·82759	...	...		0·18181	0·01178	
Groat or fourpence	29·09090	1·88506	...	...		0·12121	0·00785	
Threepence	21·81818	1·41379	...	...		0·09090	0·00589	
Twopence	14·54545	0·94253	...	...		0·06060	0·00392	
Penny	7·27272	0·47126		...		0·03030	0·00196	
Bronze—								
Penny	145·83333	9·44984	...	...	Mixed metal:—copper, tin, and zinc.	2·91666	0·18899	None.
Halfpenny	87·50000	5·66990	...	...		1·75000	0·11339	
Farthing	43·75000	2·83495	...	...		0·87500	0·05669	

The weight and fineness of the coins specified in this schedule are according to what is provided by the Act 56 Geo. III. c. 68, that the gold coin of the United Kingdom of Great Britain and Ireland should hold such weight and fineness as were prescribed in the then existing mint indenture, that is to say, that there should be nine hundred and thirty-four sovereigns and one ten-shilling piece contained in 20 ℔ weight troy of standard gold, of the fineness, at the trial of the same, of 22 carats fine gold and 2 carats of alloy in the pound weight troy, and further, as regards silver coin, that there should be sixty-six shillings in every pound troy of standard silver of the fineness of 11 ounces 2 pennyweights of fine silver and 18 pennyweights of alloy in every pound weight troy.

The present standard of fineness for gold, 22 parts fine or pure gold and 2 parts of alloyed metal, was finally adopted in the reign of Charles II., and has remained unchanged up to the present time. Before the passing of the Act determining this standard considerable changes had been made from time to time, the highest degree of fineness having been reached in the reign of Henry III., when the first gold coins were struck of the standard of 24 carats pure gold. The standard of fineness for gold at some different periods may be seen from the following table, which shows the composition of some of the ancient gold trial plates, of which portions are preserved in the Mint:—

Date.	Standard prescribed by Law.		Standard found by Assay	Remedy or Permitted Variation in Carats and in Thousandths.
	In Carats and Grains.	Decimal Equivalent.		
1349	...	...	...	1/3 carat, or 13·9
1477	23 3½	994·8	Gold 993·5	1/8 „ „ 5·2
1527	22 0	916·6	„ 915·5	1/6 „ „ 6·9
1543 (?)	23 0	958·4	„ 954·4	1/6 „ „ 6·9
1553	23 3½	994·8	„ 990·3	1/6 „ „ 6·9
1560	22 0	916·6	„ 913·7	1/6 „ „ 6·9
1560	23 3½	994·8	„ 994·3	1/8 „ „ 5·2
1593	22 0	916·6	„ 915·9	1/6 „ „ 6·9
1605	23 3½	994·8	„ 990·3	1/8 „ „ 5·2
1649	22 0	916·6	„ 913·0	1/6 „ „ 6·9
1660	23 3½	994·8	„ 990·9	1/6 „ „ 6 9
1660	22 0	916·6	„ 912·9	1/6 „ „ 6·9
1688	22 0	916·6	„ 914·6	1/6 „ „ 6·9
1707	22 0	916·6	„ 917·1	1/6 „ „ 6·9
1728	22 0	916·6	„ 916·1	1/6 „ „ 6·9
1829	22 0	916·6	„ 915·3	1/16 „ „ 2·6
1873	22 0	916·6	„ 916·61	2·0
1873	Supplementary plate.		Pure gold.	...

The earliest trial plate of which there is any record was made in the seventeenth year of Edward IV. Before that time it would seem that the coins were compared with others known to be of standard fineness, since among the Cotton MSS. is preserved the account of the trial of the pyx of gold nobles in 1349, when the coins were compared with an ounce of florins of Florence kept in the Treasury as standards. The first gold coins were 24 carats fine or pure gold. Edward III. caused coins to be struck of 23 carats 3½ grains fine in 1345, but no trial plate of this standard was made until 1477. Henry VIII. lowered the standard to 22 carats, but caused coins to be struck both of that and the former standards. The greatest debasement of the standard ever reached in England was in 1546, when it sunk as low as 20 carats. It reached a low point in the early part of Edward VI.'s reign, but was raised towards the end of it to 22 carats; and it was still further raised to 23 carats 3½ grains by Elizabeth, who, however, caused gold coins of 22 carats also to be struck. Charles II. on his accession rejected the trial plates of the standard of 22 carats which had been made under the Commonwealth, and caused others to be made of the standard of 23 carats 3½ grains. No coins, however, appear to have been struck of this standard. The same monarch afterwards fixed the standard at 22 carats; and no variation in the legal standard has occurred since that time. The last new trial plates, made in 1873, were alloyed with copper only, in order that they might correspond with the composition of the British gold coins, former plates having been alloyed with silver and copper. At the same time supplementary plates of pure gold and silver were prepared in order that the greatest possible accuracy might be secured.

The present standard of fineness of silver for coinage was fixed at a very early period, but has been subject to considerable variation since the reign of Edward I., the first English monarch who debased the silver coinage. In the reign of Henry VIII. it was once reduced as low as 4 ounces of silver to 8 of alloying metal, and Edward VI. reduced it even lower. It was restored by Elizabeth to the original standard.

The following table shows the composition of some of the ancient silver trial plates of which portions have been preserved in the Mint:—

Date.	Standard prescribed by Law.		Standard found by Assay.	Remedy or Permitted Variation in Dwts. and in Thousandths.
	In ozs. and dwts.	Decimal Equivalent.		
No date.	...	...	Silver 757·4	...
1477	11 2	925·0	„ 923·5	2 dwts.
1527 (?)	...	...	„ 885·5	...
1542	9 6	775·0	„ 763·6	3 dwts. (?), or 12·5
1553	11 2	925·0	„ 927·0	2 dwts., or 8·4
1560	11 2	925·0	„ 930·2	2 „ „ 8·4
1600	3 0	250·0	„ 252·0	3 „ „ 12·5
1601	11 2	925·0	„ 925·1	2 „ „ 8·4
1604	11 2	925·0	„ 922·7	2 dwts.
1649	11 2	925·0	„ 923·7	2 „
1660	11 2	925·0	„ 924·2	2 dwts., or 8·4
1688	11 2	925·0	„ 922·0	2 „ „ 8·4
1707	11 2	925·0	„ 922·0	2 „ „ 8·4
1728	11 2	925·0	„ 928·9	2 dwts.
1829	11 2	925·0	„ 925·0	1 dwt., or 4·2
1873	11 2	925·0	„ 924·96	4·0
1873	Supplementary plate.		Pure silver.	...

The alloy used for the bronze coinage is composed of 95 per cent. of copper, 4 of tin, and 1 of zinc. The bronze coinage superseded the old copper coinage in 1860, the latter having been in use since the reign of Charles II. The vicissitudes of the copper coinage were even greater than those of the superior coinages, coins for Ireland having been issued at one time of pewter and of other alloys in which scarcely any copper was contained.

The annual testing of the standard of gold and silver coins, called the trial of the pyx, from the "pyx" or chest in which the coins to be examined are kept, is a ceremony of very ancient institution. It arose from the circumstance that the mint master was originally a contractor, under the crown, for the manufacture of the coinage, and it was therefore necessary that periodical examinations of the coins should be held in order to ascertain that the terms of his contract had been complied with. At the present day, when the mint master is no longer a contractor, but an officer of the crown, the trial of the pyx has a somewhat different object; but it would appear from the description of these periodical examinations in some of the earliest mint records that but little change has taken place in the manner of conducting them. The finished coins are delivered to the mint master in weights called "journey weights,"

supposed to be the weight of coin which could be manufactured in a day when the operations of coining were performed by the hand. The journey weight of gold is 15 lb troy, coined into 701 sovereigns or 1402 half-sovereigns. The journey weight of silver is 60 lb troy. From each journey weight a coin is taken and deposited in the "pyx" or chest for the annual trial. This is made by the freemen of the goldsmiths' company under the direction of the crown in the presence of the queen's remembrancer, who administers the oath to the jury and presides over the proceedings. The coins selected for trial are compared with pieces cut from trial plates of standard fineness, which are in the keeping of the warden of the standards, these pieces being assayed against the coins under examination. If the coins are found to be of the standard fineness and weight, within certain limits, a verdict to that effect is drawn up by the jurors and presented to the Treasury.

In consequence of the impossibility of ensuring an absolutely exact admixture of metals in coining, it has been found necessary at all times to allow to the mint master a certain margin, or "remedy," within which coins may vary in weight and fineness from the fixed standard and still be considered of the current standard. The remedy of fineness for English gold coin is now fixed at 2 parts per 1000. The great importance of maintaining the standard of fineness for gold will be evident when it is stated that the variation of $\frac{1}{10}$ of a millième (or thousandth part) above or below the standard causes a gain or loss of £100 in every million sterling. Gold coins would be within the remedy of fineness permitted by law if the amount of precious metal contained in them varied from 914·6 to 918·6 parts in 1000; and, although this remedy cannot be considered to be more than would meet occasional and unavoidable deviation from the exact standard, still, in the case of gold, but a very small part of the remedy of fineness is actually used, the coins seldom falling below 916·3 parts of gold in 1000, or rising above 917·0, while the mean composition of many millions of coins issued from the mint is often of the precise legal standard, 916·66. The remedy of fineness for silver coin, which appears to have been always greater than that for gold coin, is 4 parts per 1000. The remedy of weight for gold is 1·6 per 1000 parts, that for silver 4·17, and that for bronze 20. Extreme care is taken to prevent the issue from the mint of any coins that exceed these permitted variations in weight and standard, each coin being weighed separately, and all those found to be above or below the standard being returned to the melting-house.

Since the real value of the gold coinage is the same as its nominal value, it is of the first importance that gold coins which are below the standard weight should not be allowed to circulate, otherwise holders of large quantities of gold coin are liable to considerable loss. After a certain amount of wear a gold coin in passing from hand to hand loses weight and becomes legally uncurrent. By the Coinage Act it is made compulsory for every person to "cut, break, or deface" any coin tendered to him in payment which is below the current weight, the person tendering it bearing the loss; but, as no penalty is imposed for disregard of this obligation, the law is practically without effect. The withdrawal of light coin from circulation was formerly accomplished solely by the Bank of England, the mint regulations making provision for the receipt of gold tendered for coinage only in the form of bars. The bank undertook to purchase the light gold from the public at the rate of £3, 17s. 6½d. an ounce, a price which, as compared with the mint value of £3, 17s. 10½d., entailed a loss of no less than 4d. an ounce on the seller. This loss was occasioned chiefly by the circumstance that the bank, being obliged before sending the light gold to the mint for recoinage to melt, assay, and cast it into bars, found it necessary to deduct the sum of 2½d. an ounce from the rate of £3, 17s. 9d. an ounce at which it was allowed by statute to purchase gold for coinage, in order to cover the expense of these operations and the loss incident to them. The heavy loss in price, added to that from deficient weight, occasioned constant disregard of the law requiring all light coin to be cut or defaced, and consequently a large amount of light gold continued to be circulated. After the passing of the Coinage Act in 1870, accordingly, fresh regulations were made, by which the mint authorities undertook to receive light gold coin for recoinage, returning to the importer the full mint value of £3, 17s. 10½d. an ounce, thus reducing the loss to that arising from deficiency of weight only. As the Bank of England was enabled by these regulations to raise its price for light gold to the rate of £3, 17s. 9d., the same rate at which it is bound to purchase ingots of standard gold, greater inducements were offered to the public to send in light gold for recoinage, and its withdrawal from circulation was in consequence greatly facilitated. It is evident, however, that, as the deficiency in weight must entail some loss on the holders of light gold coin, they will be disposed to keep it in circulation as long as possible; consequently only a small proportion of the light gold received by bankers finds its way to the Bank of England and thence to the mint for recoinage. The result of some careful experiments made by the late Mr Stanley Jevons, and published by him in the *Journal of the Statistical Society* (vol. xxxi. p. 426), showed that a sovereign becomes so light as to be legally uncurrent at the end of eighteen years. The last state measure taken for the withdrawal of light gold coin from circulation was the issue of a royal proclamation in 1842 calling attention to the laws and regulations relating to light gold coin, and instructing those persons whose duty it was to enforce them to see that they were carried out. From the beginning of July 1842 to the end of March 1845 £14,000,000 in light gold coin was withdrawn from circulation and recoined. This amount was estimated to represent 95 per cent. of the whole of the light gold then in circulation. In order to facilitate this withdrawal the Treasury had in June 1842 entered into arrangements with the Bank of England by which the bank was enabled to purchase light gold on behalf of the Government, at the full mint value of £3, 17s. 10½d. an ounce. Light coin, however, continued to be sent into the bank for some time after it had reverted to its original rate of payment for light gold, *i.e.*, £3, 17s. 6½d. an ounce. The expense to the state of this withdrawal, including the expenses of recoinage, was £67,816. As no important withdrawal of worn gold coin has occurred since that time, it is evident that a large amount of light gold must be at the present time in circulation, and that the loss in weight must be considerably greater than that of the coins withdrawn in 1842, the oldest of which were not more than twenty-five years old, the first issue having taken place in 1817. It has been proved by experiment that the average loss of weight in worn sovereigns and half-sovereigns now in circulation is about 3d. in each sovereign, and that the deficiency in fineness of a large proportion of the coin amounts to about £400 per million. This deficiency arises from the trial plate of 1829, which determined the standard of a portion of the coins still in circulation, being itself below the legal standard. Taking the gold circulation at £100,000,000, of which about 50 per cent. is light, it is estimated that the amount to be recoined cannot be less than £50,000,000, on which the loss from deficiency of gold, both in weight and fineness, must be reckoned at about £650,000, independent of the expenses of recoinage.

In the case of the silver coinage, the loss consequent on the

withdrawal and recoinage of silver money is now covered by the seigniorage arising from the difference between the real and the nominal value of the coins. Before the adoption of gold as the sole standard of value, the conditions attending the withdrawal and recoinage of silver were much the same as those for gold. In the period between the reign of Charles II. and the accession of William III. the condition of the silver coinage became so unsatisfactory as to demand the attention of parliament. A recommendation made at the suggestion of Sir Isaac Newton for a recoinage of silver was at first strenuously opposed, but was finally adopted. In the course of the discussion the question of raising the standard of weight and fineness arose, and this important change would probably have been made but for the representations of Locke, who warmly took up the question and convinced the Government of the desirability of preserving the established standard. In the great recoinage of silver, the loss arising from clipped and defaced coin was borne by the public, the money being raised by means of a special tax on glass windows. The silver reissued at this time amounted to £7,000,000, and the tax raised to cover loss and the expenses of coinage to £1,200,000. The work of this recoinage was so great that the resources of the mint in London were found to be unequal to the pressure put upon them, and therefore mints were either revived or established for the first time in a few of the large provincial towns. In addition to this ten furnaces were erected behind the Treasury at Whitehall to melt down the old pieces. By these means the renovation of the silver coinage was completed within the year. The new silver coins then issued were the first which had milled edges, the milling having been introduced in order to prevent clipping.

The mode in which the silver currency is distributed throughout the kingdom is explained by the late Mr George Forbes, cashier of the Bank of England, as follows:—

Every banker in the kingdom has a banker who is his agent in London. Every London banker has an account with the Bank of England. In the Bank of England there is a department devoted to the issue and receipt of silver coin. If in a district there is a deficiency of silver currency, the bankers of the district are the first to find it out. They at once write to their London agents, who draw on their account with the Bank of England, and obtain what silver is required, which they send to the country banker. On the other hand, if there is a surplus of silver in a district it accumulates in the coffers of the local bankers, who send it up to their London agents, and they send it into the Bank of England. If there is a general demand for silver currency, the stock which the Bank of England endeavours to keep on hand becomes unduly diminished, and immediate notice of the fact is conveyed to the mint authorities, who proceed with all convenient speed to coin a supply of florins, shillings, sixpences, or of all of these coins, as the nature of the demand may require.

Gold bullion for coinage is supplied to the mint almost entirely by the Bank of England, the bank being bound by law to purchase at the rate of £3, 17s. 9d. an ounce any gold bullion of the legal standard which the public may bring for sale. Private individuals are permitted to bring bullion to the mint, and to receive back the full amount (at £3, 17s. 10½d. an ounce) converted into coin, free of any charge for loss or manufacture; but, as they are subject to considerable delay, all "importations" of bullion being converted into coin in the order in which they are brought to the mint, the public practically prefer to sell their bullion to the bank, and receive its value without delay. In order to be accepted by the bank, the bullion must be cast into ingots and assayed, a guarantee being given by certain recognized assayers that the gold is of a certain standard fineness. This is known as the "trade assay." When the bank requires gold to be struck, due notice is sent to the deputy master, and on a fixed day the bullion is conveyed to the mint and delivered into his custody. It arrives in the form of ingots, each weighing about 200 ounces, the aggregate value of each importation being about £144,000. When the ingots arrive at the mint a small sample is taken from each and assayed,[1] the result being sent to the authorities of the bank in order that it may be compared with that of the trade assay. If the bank authorities find that the two assays agree, within certain limits, as to weight and fineness, the ingots are immediately sent to the operative department of the mint to be converted into coin. The mint assay affords the basis for calculating the amount of copper, the alloying metal, that must be melted with the gold in order to produce the standard prescribed by law. The case of silver is somewhat different, the bullion being purchased by the department at its market value, which varies from year to year. During the ten years ending 1881 the average price of silver bullion sank gradually from $60\frac{5}{16}$d. to $51\frac{13}{16}$d. The silver bullion arrives at the mint in the form of ingots, each of which weighs about 1000 ounces, the value of each set of ingots varying considerably. The ingots, both of gold and silver, are weighed on a balance capable of turning with 1 grain when loaded with 1200 ounces.

The operations of coining have undergone some slight changes with the introduction of new machinery and the increased extent of the Royal Mint, since the reconstruction of the operative department in 1881.[2] The plan (fig. 1) shows the present arrangement of the operative department.

The operations employed in the manufacture of gold and silver coin are as follows (incidental operations being printed in smaller type):—

I. Assaying the bullion.

II. Melting the metal.

(*a*) Addition of the amount of copper necessary to form the prescribed alloy; (*b*) pouring the metal into moulds so as to form bars; (*c*) dressing these bars to remove rough edges and hollow ends; (*d*) recovery of precious metals from crucibles and "sweep."

III. Assaying portions of metal cut from certain bars, to ascertain whether sufficient accuracy has been attained in the standard fineness.

IV. Rolling the bars into strips or "fillets."

Annealing the fillets (in some cases).

V. Adjusting the fillets by a final rolling, and in some cases by the use of the drawbench.

Testing the fillets to ascertain whether they are of sufficient accuracy as regards thickness.

VI. Cutting out disks or blanks from the fillets.

Adjusting the blanks in weight (in some mints).

VII. Edge-rolling the blanks to produce a raised rim.

Annealing the blanks and (in some cases) "blanching" or "pickling" them in dilute acid.

VIII. Coining, or stamping the device on the blanks, by means of engraved steel dies.

Milling the edges of the blanks or (in some cases) impressing a device, inscription, or ornament upon them.

IX. Weighing each coin, usually by the aid of automatic machinery.

X. Assaying and weighing pieces taken from the finished coin before it is issued to the public.

The foregoing list will make it clear that the operations of minting consist, not simply in the mechanical production of accurately adjusted disks of metal the purity alone of

[1] The assays are conducted in the manner already described in the articles ASSAYING and GOLD.

[2] In order to provide a stock of silver coin during the temporary suspension of the work of the mint, a large coinage of silver was issued, and 50 tons of bronze coins were manufactured by contract in the autumn of 1881. The governor of the Bank of England had previously reported that the stock of gold coin held by the bank was abnormally large, and that no inconvenience would arise "if the mint were to cease coining sovereigns and half-sovereigns for a period of six months or a year or even more."

which has to be guaranteed, but in the formation of an alloy composed of precious and base metals in definite proportions. The accuracy of the "standard fineness" of the alloy after melting must be absolutely ascertained; the alloy must be protected during manufacture against a change of standard, and finally its correctness must be verified after it has been converted into coin.

The precious metals are weighed on entering the mint, as well as during various stages in the manufacture of coin. The finished coins are also weighed in bulk before they are issued to the public.

The operations incidental to the coinage of bronze and silver differ from those described in relation to gold in some unimportant details only; and the weight and composition of the bronze coins are not so carefully guarded as is the case with gold and silver.

Subjoined are the details of the operations involved in the conversion of bullion into coin at the British mint.

Melting the metal.

After being assayed and weighed in the manner already described the bullion is taken to the melting-house, where the details of treatment for silver and gold respectively differ somewhat. (The subsequent operations are nearly identical for both metals.) The silver melting-house (see fig. 1) contains eight furnaces, of the kind shown at A fig. 2, the part of the furnace containing the crucibles being below the lids B, B. Crucibles of cast iron were formerly employed, but these were replaced in 1853 by wrought iron pots, which have since 1870 been in turn abandoned in favour of crucibles made of a mixture of clay and graphite, each crucible being capable of containing about 3000 oz. Such crucibles are very generally adopted throughout the Indian and Continental mints, but the form and dimensions given to them vary. The fuel employed in England is coke, about 75 lb of which are required to melt 3000 oz. of standard silver. Sufficient draught is afforded by the flue C and by a chimney about 35 feet high which communicates with it. The silver and copper are melted together;

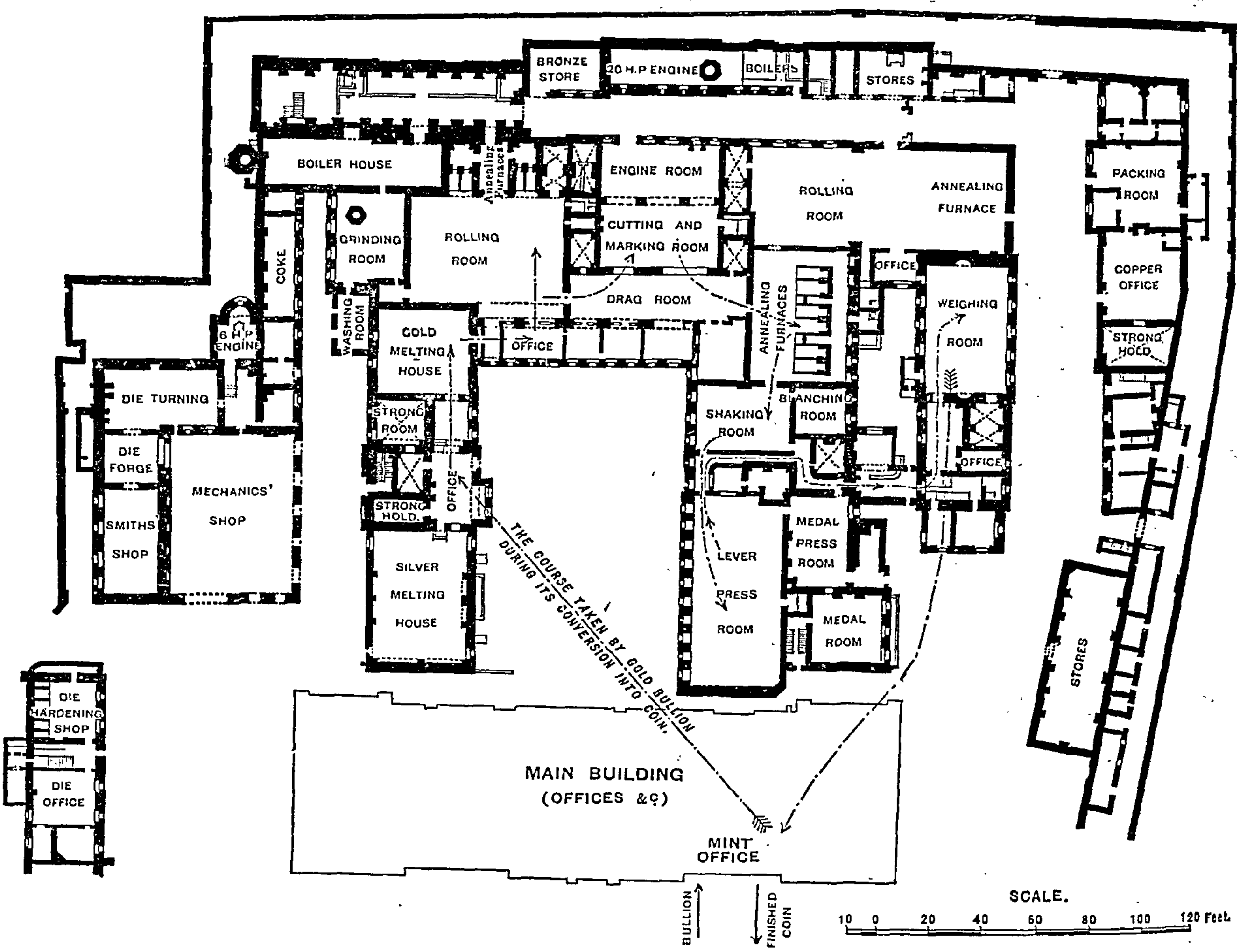


Fig. 1.—Royal Mint, Tower Hill, London. Plan showing the Operative Department as rearranged in 1881–82.

and before the metal is poured into moulds it is stirred with an iron rod having a flattened end. The surface of the molten metal is covered with a layer of charcoal to prevent oxidation of the copper. The crucible with its contents is then removed from the furnace by the aid of a crane and tongs W, and is placed in a cradle M, which can be tilted by means of a handle D. By the intervention of toothed wheels E, F, G, H, and K acting on a rack the handle turns the crucible on the fulcrum formed by a spindle, so that the contents of the crucible may be poured into the moulds N mounted on a carriage OP, running on rails Q, Q. The moulds now in use in London are of such dimensions as to enable bars to be cast 12 inches long and $\frac{3}{8}$ inch thick. The width of the bars varies, according to the coin to be produced, from $1\frac{3}{4}$ to $2\frac{5}{8}$ inches.

When the metal has solidified in the moulds it is removed, and the bars are trimmed by the aid of a revolving circular file, their ends being cut off and returned to the melting pot. Portions of metal are then cut from certain of the bars, and sent to the assay department. The bars are weighed before they pass to the subsequent operations of coinage, in order that the amount of metal retained by the crucibles or carried into the flues may be ascertained. Gold bullion is melted in a similar way, but the crucibles are smaller, and contain only 1200 oz. Their contents are poured by hand into moulds, one end of the tongs by which the crucible is grasped being supported by a chain and suspended from the roof.[1] In many Continental mints it is very generally the practice to leave the crucible containing the precious metals in the furnace, and to pour the contents into the moulds by the aid of small ladles of wrought iron lined with clay.

It has been pointed out in Gold (vol. x. p. 751) that minute quantities of certain metals render standard gold extremely brittle and unfit for coinage. If either the gold bullion or the copper used as an alloying metal should be impure, brittle bars will be the result. Should this prove to be the case, the bars are re-

[1] A new form of furnace devised by M. A. Piat of Paris has recently been introduced. In these furnaces the portion which contains the crucible may be detached from the flue, so as to admit of the molten metal being poured into moulds without removing the crucible from the incandescent fuel. Four of such furnaces have been fitted up in the gold melting-house, but have not as yet been used for gold melting; in the melting of silver and bronze, however, they are known to effect considerable economy in labour, fuel, and crucibles.

melted and chlorine gas is passed through the molten mass in the manner described in GOLD, vol. x. p. 750.

The engine-room (shown in fig. 1) contains three 60-horse-power vertical condensing engines, which are provided with Corlis valves, and are specially devised for meeting the constantly varying strain to which they are subjected by the machinery, the whole of which they are capable of driving. The central engine acts directly on either or both of the rolling rooms placed on each side of the engine-house. There is, however, an additional 20-horse-power compound beam engine usually employed, in connexion with the pumps of a deep artesian well.

Rolling. Into one or other of these rooms the bars which have been cast in the melting-house are brought, and are rolled into strips the thickness of which depends on the kind of coins to be produced. Gold is rolled in one room and silver or bronze in the other. The details of manipulation involved in the conversion of gold, silver, or bronze bars into coin, however, do not differ materially, and the coinage of sovereigns will therefore be taken as typical.

Each room contains six pairs of rolls, the diameter of the rolls varying from 10 to 14 inches. Smaller diameters are employed in most European mints, but on the other hand the use of very narrow rolls of far larger diameter has often been suggested, and there appears to be good ground for the belief that the rigidity of such rolls would enable strips or fillets of more uniform thickness to be

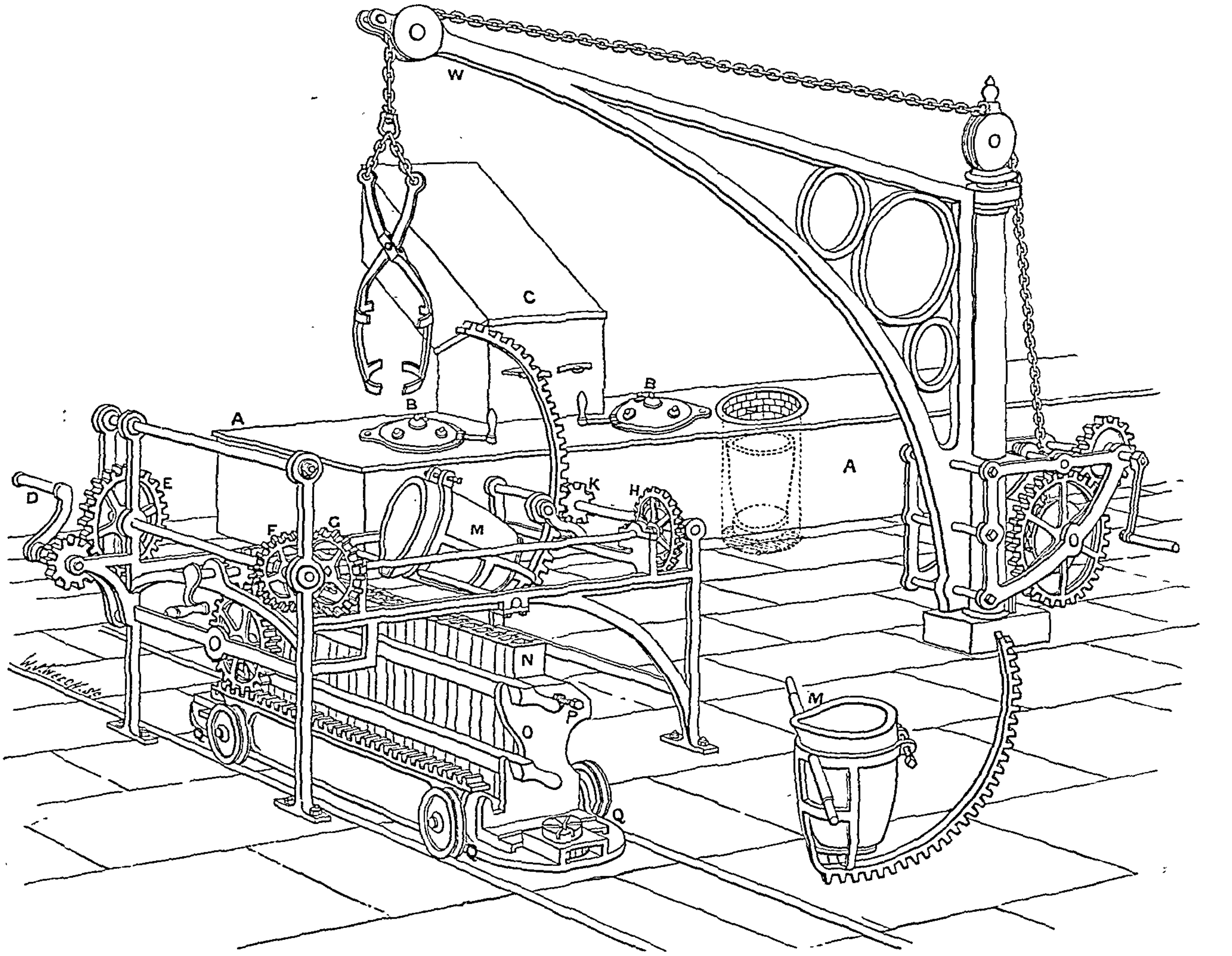


FIG. 2.—Furnace Apparatus.

produced than is the case at present. The iron frame CC (fig. 3) is firmly bolted to the stone D, which rests on a solid foundation EE. This frame supports the two rolls A, B, the lower of which B revolves, but is not, like the upper, capable of adjustment in a ver-

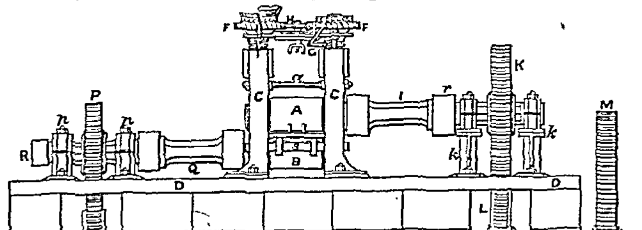


FIG. 3.—Rolls.

tical plane. The upper roll is centred in bearings, and may be raised or lowered by means of screws connected with toothed wheels F, F, which are turned by a handle G, both wheels being moved simultaneously by worms on the rod H. The bearings of the upper roll are connected by vertical rods with weights below the level of the floor; and, as it rises with the screws, it can thus be readily adjusted in a line exactly parallel with the lower roll, at a sufficient distance from it to admit the bar which is to be reduced to a strip or fillet. The rolls are turned by the shaft NN, the main wheel M, and the gearing K, L, O, P. The sockets *r* by which the upper roll is connected with the gearing by the shaft I are not rigid, as is the case with the shaft Q of the lower roll, but admit of the adjustment of the roll. The portion of the roll used is determined by a guide a little wider than the bar.[1] The rolls throughout this department are driven at the rate of about 32 revolutions in a minute. The iron frame CC is braced by rods *a*, *s*; and blocks bearing the driving shafts are shown at *k*, *k*, *p*, *p*.

The initial thickness of a sovereign bar is $\frac{5}{8}$ths of an inch. The bars are weighed out to the workmen in batches of about sixty bars, an entire batch being passed through the rolls under precisely the same conditions of adjustment. The bars are only slightly reduced in width by repeated passages through the rolls, but are successively reduced in thickness in the first stages of the rolling by $\frac{1}{10}$th of an

[1] In the second rolling room, shown in the plan on the right of the engine-house, the frames and gearing of the rolls are of newer pattern than those in the first room. In some of the six pairs the bottom rolls revolve and drive the upper ones. In the pair of "breaking-down" rolls in this room,—that is, the roll by which the fillets are first treated,—the upper roll is stationary, the lower roll alone revolving. The necessary "bite" is given to the fillet, when its end is introduced, by slightly turning the upper roll by means of a ratchet-wheel and lever.

inch, while in the later stages the reduction in thickness at each passage through the rolls is less than $\frac{1}{100}$th of an inch, and finally one or two "spring pinches" are given to the bars by simply passing them through the rolls without altering the adjustment. The testing of the fillets, to ascertain whether they are of the accurate thickness, is effected by the aid of the gauge plate (fig. 4), which consists of two steel bars set at a low angle in relation to each other and graduated to $\frac{1}{1000}$th of an inch.

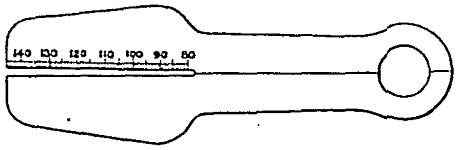


FIG. 4.—Gauge Plate.

It will be evident that the weight of the finished coin depends upon the thickness of the fillets; and to show how accurately the rolling must be performed it may be pointed out that, in the case of the half-sovereign, a variation of $\frac{1}{20000}$th of an inch above or below the accurate thickness (or a range of $\frac{1}{10000}$th of an inch) throws the coin out of "remedy."

The repeated passage through the rolls is attended by a considerable increase of hardness in the metal, and it is therefore in some cases necessary to anneal the fillets repeatedly during the rolling. In the case of fillets for sovereigns the annealing may be entirely dispensed with if the initial thickness of the bars does not exceed $\frac{3}{8}$ths of an inch. Fillets for half-sovereigns have only to be annealed once. In some European mints the fillets are annealed frequently; in one mint the operation is performed after each passage through the rolls. The furnace used for the purpose is generally so arranged as to permit the flame to play over the fillets, which are sometimes freely exposed to its action, but are more often enclosed in cases or tubes. Muffle furnaces are frequently used. The furnace used in the Royal Mint is a simple form of reverberatory furnace. The final rolling is given by a pair of finishing rolls capable of more accurate adjustment than the "breaking-down" rolls.

The fillets of gold or silver are in some cases, though not always, submitted to an appliance known as the drag bench, shown in figs. 5, 6, 7. Its object is to equalize the thickness of the fillets by drawing them between steel cylinders. The ends of the fillets are Drag bench.

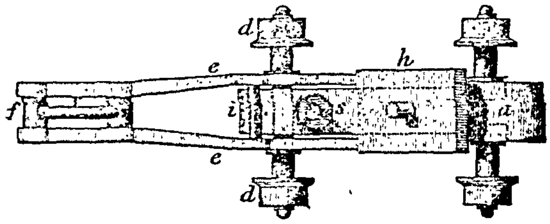


Fig. 5.

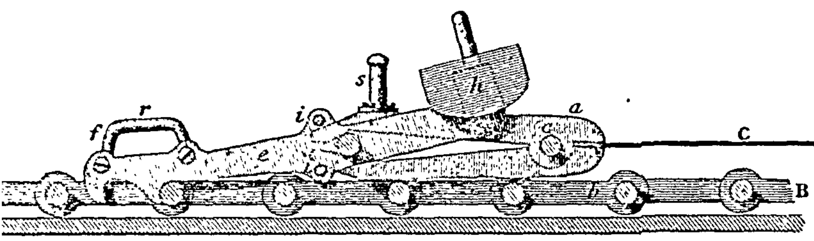


Fig. 6.

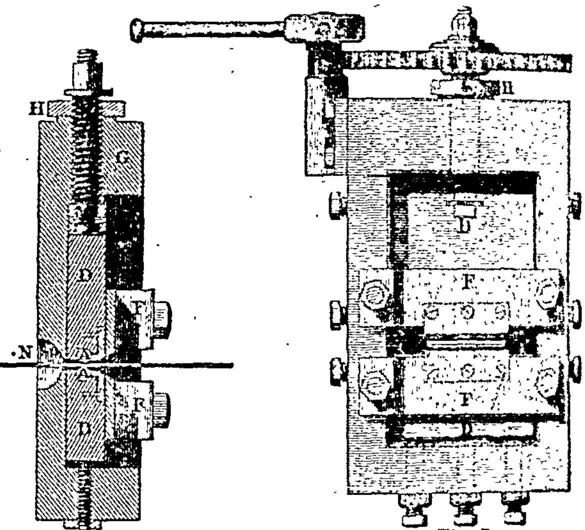


Fig. 7.

FIGS. 5, 6, 7.—Drag Bench.

first flattened in a little appliance, which need not be described. The essential feature of the machine now used in the mint consists of two small steel cylinders A, A, which do not revolve, and are held in position in the plates D, D by clamp pieces F, F screwed against them. The portions of metal may be adjusted by the aid of a wheel and screw H (figs. 6, 7), and by small adjusting screws f, f. The part of the machine containing the steel cylinders is fixed at the end of a long bench, and gearing at the other end of this bench drives an endless chain BB (fig. 6), one link or other of which catches the carriage, shown in plan in fig. 5, and drags it along as soon as its end f is depressed by the handle r. The carriage runs on the wheels d, d. The drawing of the fillet C is conducted as follows. Its flattened end is introduced between the steel cylinders, and is grasped by the jaws a. The jaws turn on the pin e, and while the fillet is being dragged through the cylinders the axle of the wheels d, d tends to increase the grip of the jaws by acting on their inclined ends. Directly the strain on the

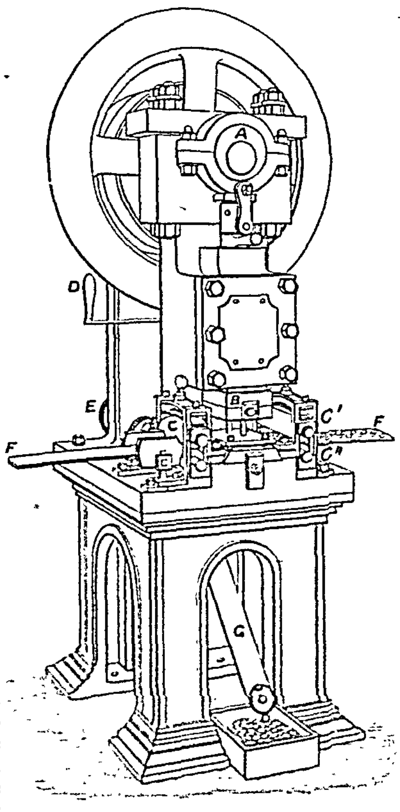


FIG. 8.—Cutting Machine.

fillet is released, the pins i, i and the weight h loosen the jaws and at the same time raise the end of the carriage so as to arrest its further progress along the bench. The carriage is then moved forward by the handle s until the jaws enter the hollowed portion N and grasp another fillet.

Formerly—when fillets were rolled from thick bars—this appliance played a more important part in coining operations than at present. It is now only used for fillets from which sovereigns and half-sovereigns are to be produced. Before fillets are passed on to the next operation—that of cutting from them the disks or blanks destined to form the coin—they are carefully tested by a skilful workman called the "tryer," who cuts one or two blanks from the sides of each fillet by the aid of a cutter worked by hand. These blanks are weighed on a delicate balance against a standard weight, and the experience of the operator enables him to determine whether the variation from the exact weight will justify his sending the fillets forward to the cutting room. In any case he divides the fillets into two or more classes for a reason that will be explained presently. Trying.

The cutters employed in the mint until quite recently were of complicated construction, but these have been replaced by a simple machine (fig. 8) which, by the revolution of an eccentric A, causes two short steel cylinders, mounted on a block of iron B suitably guided, to enter two holes firmly fixed in a plate on the bed of the machine. When the fillet FF is interposed between the short cylinders and the holes, the former force disks of metal through the holes, the fillet being advanced at each stroke of the machine by small gripping rolls C, C′, C″ actuated by a ratchet-wheel E, driven from the shaft which bears the eccentric A. The disks pass down the tube G to a receptacle placed on the floor. In the case of very large silver coins, only one disk is cut in the width of the fillet, and in some few mints disks for gold coin are also cut in this way, but it is far more usual to cut two disks in the width of the fillet, the position of the cutters being so arranged as to remove blanks in the manner shown in fig. 9. In cutting disks for bronze coin extreme precision is not necessary, and it has therefore been found possible to obtain five at each stroke of the machine. Cutting blanks.

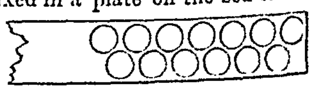


Fig. 9.

It will be evident that the rough classification of the fillets according to their thickness, to which reference has already been made, renders it easy to compensate for slight irregularities in thickness caused by rolling, by employing cutters of a slightly larger diameter than the standard size for fillets which are too thin.

The fillets after the removal of the disks present the perforated appearance shown in fig. 9. The residual metal, called "scissel," which amounts to from 25 to 30 per cent. of the metal operated upon, is returned to the melting-house in bundles weighing 180 oz. It may be mentioned here that all attempts to cut disks or blanks for coinage from the ends of rods or cylinders, and thus to avoid the production of scissel, have hitherto failed.

Adjustment of blanks.

The next operation to which the blanks are submitted varies in different mints. In some, each blank is weighed by hand or by automatic machinery, and each blank that is too heavy is adjusted either to an exact weight or to within the remedy prescribed by law. On the Continent it is very generally the practice to adjust blanks by the aid of a file, or by a machine that removes a fine shaving of metal from the surface of the blank. In mints where mechanical adjustment is adopted there is a tendency to produce "too heavy" blanks in the rolling and cutting departments, as it is impossible to adjust blanks which are too light.[1]

In the London mint finished coin alone is weighed, so that the blanks after leaving the cutting room pass directly to an edge-rolling machine, which thickens the edge of each blank so as to form a rim intended to protect the impression on the finished coin. The operation of edge-rolling is called "marking," and the method of conducting it varies considerably in different mints.

In the Royal Mint the blanks are made to pass in quick succession, at the rate of six hundred a minute, between a circular groove in the face of a revolving steel disk and a groove in a fixed block placed parallel to the face of the revolving disk. The groove in the block exactly corresponds to that on the disk; and, as the distance between the block and the disk is slightly less than the diameter of the blank submitted to the operation, the result is that before the blank escapes from the machine its edge has been thickened. The operation may be varied by admitting the blanks between a groove in the periphery of a revolving wheel and a groove in a segmented block, placed at a distance from the wheel rather less than the diameter of the blank. The wheel and block may be either vertical or horizontal.

In some cases the edges of the blanks, at the same time that they are thickened, receive the impression of a legend, or inscription, or an ornamental device. When this is the case the blank is rolled between two planes, one of which is fixed and bears the device, while the other has a reciprocating motion imparted to it, or the edge of the blank receives the impression, which may be either raised or sunk, from a collar surrounding the blank in the coining press, as will be afterwards explained.

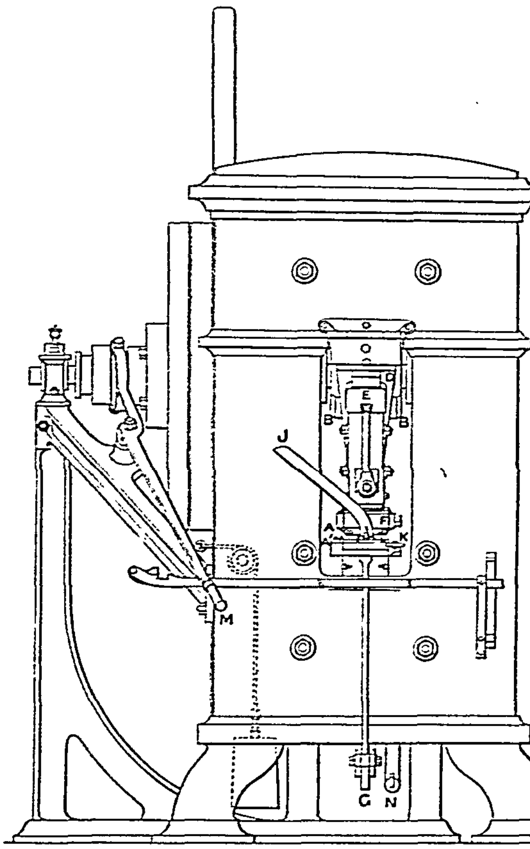


Fig. 10.

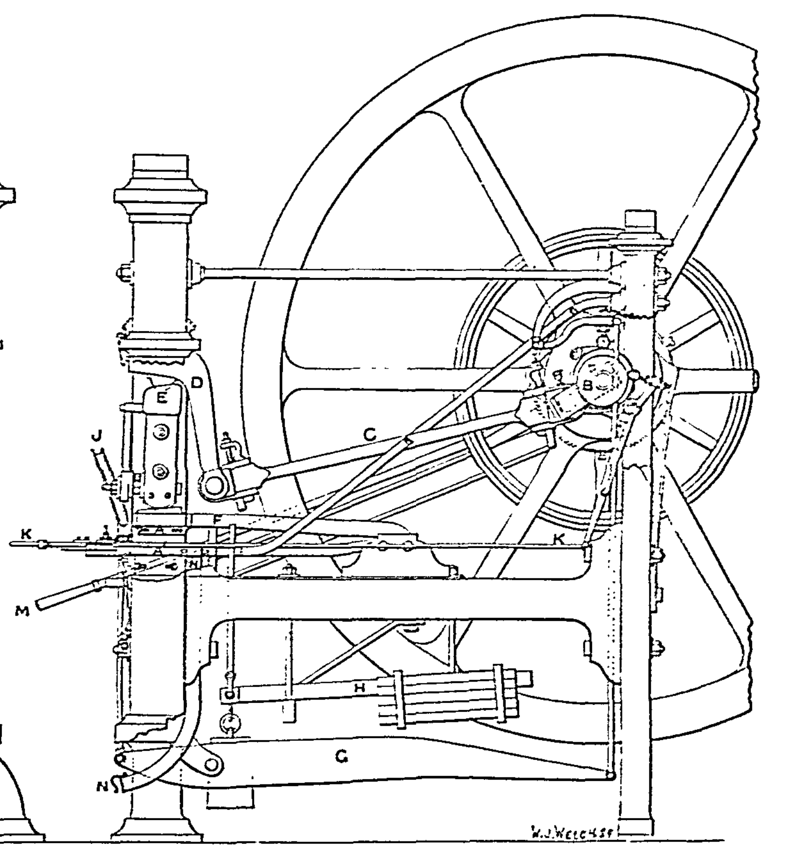


Fig. 11.

Annealing the blanks.

Before passing to the coining press the blanks either of gold or silver are annealed. In many mints the object of the heating is not only to soften the blanks before they receive the impression, but also to produce a film of oxide of copper on their surface. This is attained in various ways. In England gold blanks are placed in cylindrical crucibles of plumbago and covered with a layer of charcoal, heated in a reverberatory furnace, and when the blanks reach cherry-redness they are cooled by plunging them in water. The thin film of oxide of copper thus formed on the surface of the gold or silver blanks is readily soluble in dilute sulphuric acid, and the removal of a small portion of the alloying metal in this way constitutes "blanching" or "pickling" the coin. The method of conducting the operation varies somewhat in different mints, mainly, however, in the strength of the acid used, which varies from 3° to 5° of the hydrometer of Baumé. The solution is sometimes heated to 96° to 98° C., while in other cases the blanks are introduced into the solution while at a red heat. The latter method is, however, objectionable, as a dense layer of pure metal is found at the surface of the blank which is apt to protect the underlying oxide of copper from the action of the acid. The blanks are afterwards washed in pure water and dried either in sawdust or in copper vessels heated by steam jackets. The object of the process is to

[1] A description of a machine used for the adjustment of blanks will be found in *Dingler's Polytechnisches Journal* (1882, ccxlv. 61, pl. 6); and some years ago Mr J. M. Napier devised for the Indian mints a beautiful machine which first ascertains how much it is necessary to cut from each blank in order to reduce it to the standard weight, and then removes the necessary amount of metal and no more. The initial cost of such machinery, however, is considerable. In 1849 M. Diereck, director of the mint in Paris, endeavoured to substitute a chemical for a mechanical treatment by submitting the heavy gold blanks to aqua regia, which it was anticipated would bring them within the prescribed limits of accuracy. The results were not satisfactory, and the attempt was abandoned. In 1870 the present chemist of the mint, Professor W. Chandler Roberts, showed that gold alloyed with copper might be removed from heavy blanks with singular regularity by means of a suitable solvent aided by a battery. The blanks are arranged in a frame of wood and submitted to the action of a solution of cyanide of potassium, the heavy blanks forming the dissolving pole of the battery. The process was not used in the London mint, as it became evident that it could not profitably replace the present system, under which finished coins alone are weighed and the manufacture of good coin only is paid for. It was, however, introduced into the Bombay mint in 1870 by the late Mr L. G. Hines, who extended its usefulness by transferring the metal dissolved from the heavy blanks to blanks which are too light, the latter being by this means raised to the prescribed weight. The process has now fairly taken its place as an ordinary operation of coining, and its importance to the mints where it is used may be gathered from the fact that in the Indian mints no less than 1300 tons of silver were converted into coin in one year (1879), so that the saving effected by its introduction must be considerable.

improve the appearance of the finished coin by removing all traces of impurity from the surface of the blank. It has, however, been abandoned in the British mint except in the case of some of the smaller silver coins, mainly because the soft superficial layer of metal wears away with undue rapidity. Certain precautions suggested in 1869 by Mr Hill, the superintendent of the operative department, for avoiding oxidation or tarnishing of the metal during coinage rendered the abolition of the process possible.

Coining press. The blanks receive the impression which constitutes them coins from engraved dies. Each is placed in the lower of two dies, and the upper die is brought forcibly down upon it. The lateral escape of the metal is prevented by a collar which surrounds the blank while it is being struck. This collar may be either plain or engraved, and if the latter is the case any device or ornament it may bear will be imparted to the edge of the blank.

The coining presses used in various mints may be divided into three types:—(1) the screw press worked by atmospheric pressure, (2) the excentric press, and (3) the lever press. The first of these (see *Ency. Brit.*, 8th ed., vol. vii. p. 92) has now been abandoned. In the excentric press the power is applied to a shaft bearing an excentric which acts by means of a connecting rod upon a vertical slide holding the die which is brought down on the blank. This form of press is used in the mint at Constantinople, where the atmospheric screw press is also still retained. Of the third type, the lever press, there are two modifications, devised respectively by Thonnelier and by Uhlhorn. The details of the Uhlhorn press have been improved by Messrs R. Heaton & Sons of Birmingham; and, their superiority to the old vacuum screw press having been demonstrated by careful experiments, they have been finally adopted in the newly arranged mint, which contains fourteen of them. This press is shown in figs. 10 and 11. It is driven from below the floor of the press-room by bands which pass over fast and loose pulleys on the same shaft that bears the fly-wheel. The loose pulley, however, is only used when it is necessary to stop the machine entirely, as the fly-wheel is permitted to revolve without imparting motion to the shaft so long as a lever M, worked from the front of the machine, does not cause the fly-wheel to be connected with the driving wheel by means of two pins. The dies are placed in the front part of the machine (fig. 10). The lower one is firmly fixed to the bed, while the upper is held at A by the upper of two jaws F and A′, or levers, the fulcra of which are so close together as almost to coincide, the lower jaw A′ bearing the collar which encircles the blank while it is being converted into a coin; the upper jaw F, A, governed by the weighted lever H shown below the bed of the machine, has a tendency to rise a sufficient distance to admit the blank between the upper and lower die. A crank B on the shaft bearing the fly-wheel is connected by a rod C with the bent lever D, and this bent lever, acting through the toggle joint and a piece of metal E connected with the jaw that bears the

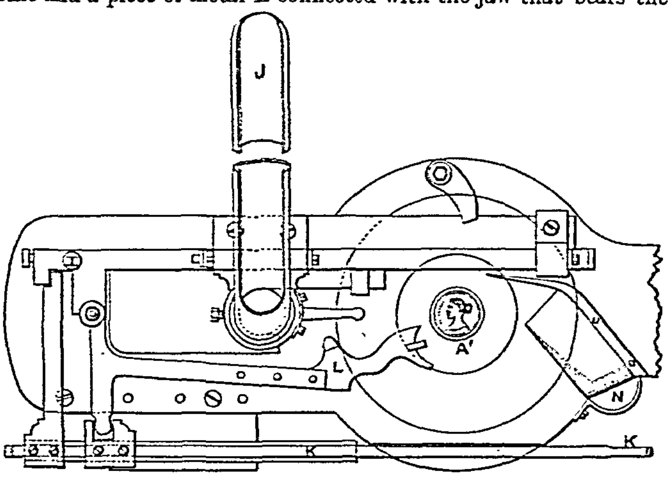


Fig. 12.

upper die, forces it down, and thus squeezes the blank between the upper and lower dies. A cam on the crank shaft acting on the lower of the two levers G shown below the bed of the machine causes the lower jaw A′ bearing the collar which surrounded the blank to be depressed sufficiently to leave the finished coin freely resting on the lower die, from whence it is driven down the shoot N by the next blank in succession. Coins are produced at rates varying from 60 to 120 a minute, 90 a minute giving the best results. The blanks to be converted into coins are placed on the slide J, and the advance of each blank in succession is regulated by the rod called the "layer on" K, the backward and forward movement of which is also regulated by an excentric on the crank shaft. The details of this part of the machine are shown in plan, fig. 12.

Automatic balance. The last operation before the finished coin is returned to the mint office for issue to the public is the weighing each gold or silver piece separately. This is effected in the American and in most Continental mints by hand, but in England automatic balances of beautiful construction are employed. They were originally devised for separating worn pieces from those of current weight, but they are now employed to distinguish between "light," "heavy," and "good" pieces, the latter alone being permitted to pass into circulation. In the newly arranged department thirty such machines are provided. Each is driven from overhead shafting by means of gut lines. The driving pulleys derive their motion from a small atmospheric engine, which is found to give more satisfactory results than would be the case if the steam-engine were employed directly. Each balance is worked by a cone pulley A (fig. 13) by a gut line passing round it from the loose pulleys B, the necessary tension being imparted to the line by means of a spring C. The tension of the line is, however, but slight, for if the action of the balance is arrested by accident the cord slides over the cone pulley A without turning it. It will be obvious that the use of the cone pulley enables the machine to be driven with varying degrees of speed. The toothed wheel D is mounted on the spindle which bears the driving pulley A, but it acts only through the intervention of a friction cheek, which is so lightly screwed against the driving wheel that it would cease to act if the machine should be accidentally deranged. The wheel D sets in motion the wheels E, E′, E″. The cam F, acting on the curved extremity of the rocking frame G, causes the slide H to bring forward one of a series of coins (arranged in the hopper I) until it rests on the plate J of the balance beam, of which beam a portion is shown in an enlarged drawing above the balance, while the plate that receives the coin is also shown in a separate drawing to the left of the machine. Another cam K then comes into play, and enables the forceps, shown at L, to release the rod M to which the balance plate J is attached. The forceps L serves to keep the rod steady while the coin is being placed on the plate J. A rod shown at N is then raised by the cam O, the lower extremity of the rod being kept steady by a pin sliding in a hole in the bottom plate of the balance, and its upper end by a pin which works into the central support of the balance beam. At the base of this rod N, and at right angles to it, there is a metallic bar QQ, the ends of which pass through stirrups in the pendants M and P from the opposite ends of the beam. The elevation of this horizontal rod by the cam O simultaneously releases both ends of the beam, and the coin placed on the beam plate has then, for the first time, a direct influence on the beam. If the coin is "too light" the counterpoise R in the cage at the end of the rod P will raise the coin, and the revolution of the machine then causes part of the cam K to permit a spring to close the forceps L and to hold the pendant M firm. An indicating finger T then falls, and by means of a horizontal lever UU′, which fits into one of three inverted steps on the bottom of the shoot V, determines over which of three orifices W, W′, W″ in the bottom plate of the balance this shoot shall stand. In the meantime the advance of the slide H brings the next piece forward, and displaces the coin which has hitherto occupied the beam plate J, forcing the coin down the shoot V, and thence through the orifice W into a receptacle, external to the balance, destined for the reception of "light coin." If this next piece should be "too heavy" it will not only raise the counterpoise R but will also elevate a little wire S, which would otherwise remain undisturbed on a support. This little wire represents the "working remedy" for the particular denomination of coin in question, which, for safety, is less by $\frac{1}{100}$th of a grain than the remedy permitted by law. The undue weight of the "heavy coin" will depress the right end of the balance beam and its pendant M to the lowest possible point, and the indicating finger T will, in this case, determine that the rod UU′ shall occupy the lowest step of the shoot V, which will consequently stand over the orifice W″ in the bottom plate of the balance which communicates with the receptacle for the "heavy" coins, and the heavy coin on the beam plate will be driven down the shoot by the next coin in succession. If the coin which is next brought forward by the slide H should be a "good" one, that is, if it is within the working "remedy," its action will be as follows. It may be slightly heavier than the counterpoise, but not sufficiently heavy to lift both the counterpoise and the remedy wire. The balance beam consequently remains approximately horizontal, and the indicating finger T will cause the rod UU′ to strike the centre step of the shoot V, which will then stand over the central orifice W′ in the bed plate which communicates with a receptacle for "good" coins, into which the coin will find its way, as soon as it is driven from the beam plate by the next coin of the series. It will be evident that this excellent appliance both weighs and classifies the coins. About twenty-three coins are passed through it in a minute.

In order to show the importance of extreme accuracy in weighing, it may be pointed out that, although by the Coinage Act of 1870 the "remedy" or allowed variation above or below the standard weight of a sovereign is only $\frac{1}{5}$th of a grain, yet in a million sterling of sovereigns the difference between the least and the greatest weight the law allows would be no less than £3244.

The manufacture of coin is not the only work which is performed in the Royal Mint. All medals issued to the

army and navy, as well as those given by the Royal Society and the university of London and some others, are struck in the mint, and their preparation forms a considerable part of the work of the die department. Since 1874 the clasps and bars for the medals have also been manufactured in the mint, whence they have been issued completely mounted. Another operation, not connected with the coinage, which is performed in the mint is the assay of the "diet" or metal scraped from the gold and silver plate manufactured at Sheffield and Birmingham under the direction of the warden of the standard of wrought plate for those towns. By Act of Parliament it is directed that this shall be brought once in each year to the mint to be assayed by the "king's assay master," under the supervision of an officer appointed by the lords of the Treasury.

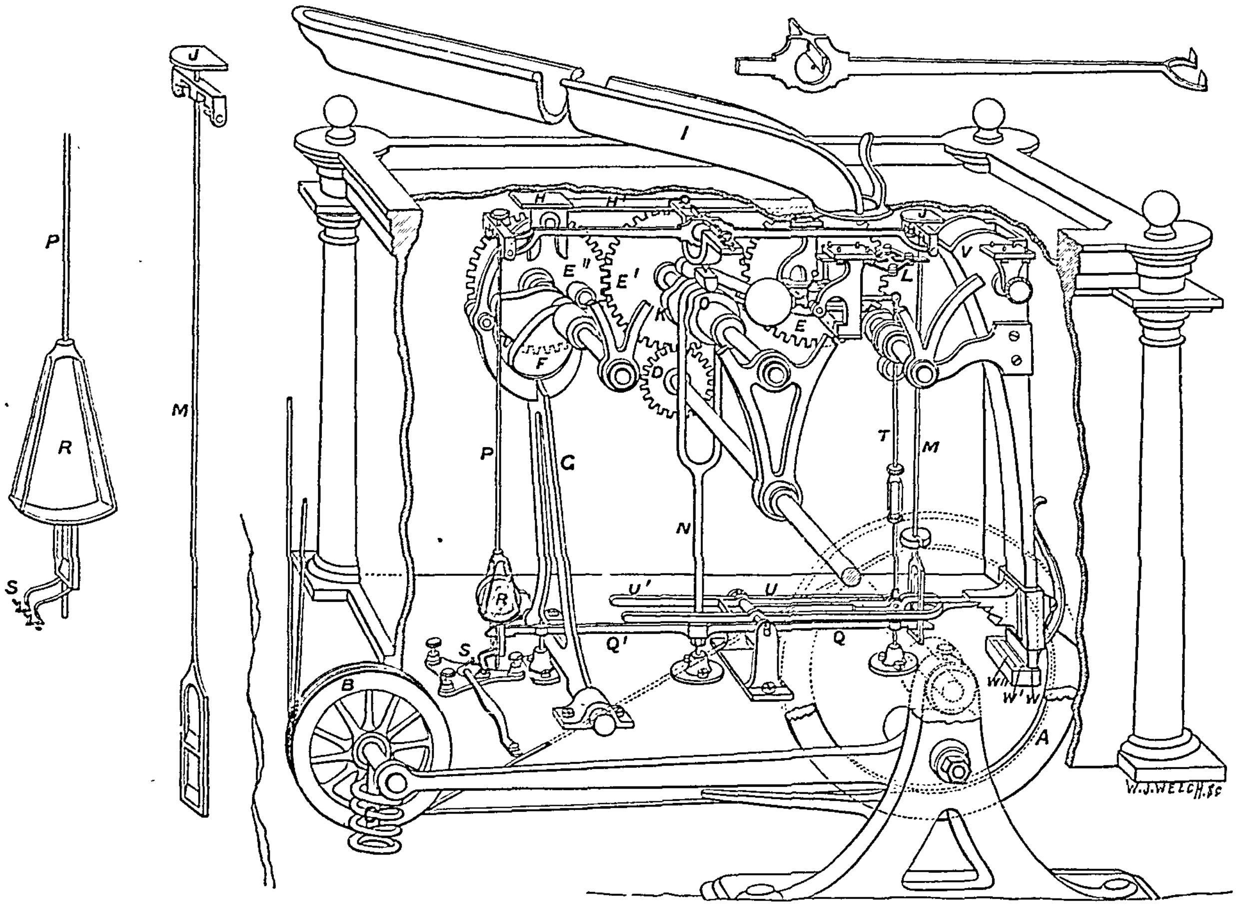


FIG. 13.—Automatic Balance.

The gold coin in circulation in Great Britain is estimated at £100,000,000. It may be well to add the following table, which gives the value of the gold and silver coinages of four of the most important foreign countries, in two recent years :—

	1880.		1881.	
	Gold.	Silver.	Gold.	Silver.
United States	£12,461,655	£5,481,941	£19,370,178	£5,587,840
Germany	1,332,430	...	326,837	...
Austria	493,605	1,674,712	485,999	1,805,734
France	...		83,646	259,910
	£14,287,690	£7,156,653	£20,266,660	£7,653,484

The value of the gold coinage of the American mints during the fiscal year ending June 1882 amounted to $89,413,447·50,—being greater than that of any previous year in their history. (W. C. R.—R. A. H.)

MINT, botanically *Mentha*, a genus of labiate plants, comprising about twenty species of perennial herbs, widely distributed throughout the temperate and sub-tropical portions of the globe. All the species are furnished with square stems, opposite, aromatic leaves, and creeping roots. The flowers are arranged in axillary cymes, which either form separate whorls or are crowded together into a terminal spike. The corolla is usually small, and of a pale purple or pinkish colour; it has four nearly equal lobes, and encloses two long and two short stamens. Great difficulty is experienced by botanists in discriminating the species of this genus by reason of the occurrence of a large number of intermediate forms, nearly three hundred of which have been named and described. Many of these varieties are permanent in consequence of being propagated by stolons.

In Britain nine of the recognized species are indigenous. *Mentha viridis*, L., or Spearmint, grows in marshy meadows, and is the species commonly used for culinary purposes; it is distinguished by its smooth, sessile leaves and lax tapering flower-spikes. *Mentha sylvestris*, L., or Horsemint, chiefly differs from the above in its coarser habit and hairy leaves, which are silky beneath, and in its denser flower-spikes. This plant is supposed to be the mint of Scripture, as it is extensively cultivated in the East, and is much used in cookery; it was one of the bitter herbs with which the paschal lamb was eaten. *M. rotundifolia* resembles the last in size and habit, but is readily distinguished by its rounded wrinkled leaves, which are shaggy beneath, and by its lanceolate bracts. The last two species usually grow on damp waste ground near roadsides. *M. aquatica*, or Capitate Mint, grows in ditches and by the side of streams, and is easily recognized by its rounded flower-spikes and stalked hairy leaves. *M. Piperita*, or Peppermint, has stalked smooth leaves and an oblong obtuse terminal spike of flowers; it is extensively culti-

vated for its volatile oil. *M. pratensis* belongs to a group of mints which, unlike the foregoing, have the flowers arranged in axillary whorls and never in terminal spikes; it otherwise bears some resemblance in foliage and habit to *M. viridis*. *M. sativa*, the Whorled Hairy Mint, grows by damp roadsides, and *M. arvensis* in cornfields; they are distinguished from *M. pratensis* by their hairy stalked leaves, which in *M. arvensis* are all equally large, but in *M. sativa* are much smaller towards the apex of the stem. *M. Pulegium*, commonly known as Pennyroyal, more rarely as Flea-mint, has small oval obtuse leaves and flowers in axillary whorls, and is remarkable for its creeping habit and peculiar odour. It differs from all the mints above described in the throat of the calyx being closed with hairs. It is met with in damp places on grassy commons, and forms a well-known domestic remedy for female disorders.

All the plants of the genus *Mentha* abound in a volatile oil, which is contained in small receptacles having the appearance of resinous dots in the leaves and stems. The odour of the oil is similar in several species, but is not distinctive, the same odour occurring in varieties of distinct species, while plants which cannot be distinguished by any botanical character possess the same odour. Thus the peppermint flavour is found in *M. Piperita*, in *M. incana*, and in Chinese and Japanese varieties of *M. arvensis*. Other forms of the last-named species growing in Ceylon and Java have the flavour of the common garden mint, *M. viridis*, and the same odour is found to a greater or less degree in *M. sylvestris*, *M. rotundifolia*, and *M. canadensis*. A bergamot scent is met with in a variety of *M. aquatica* and in forms of other species. Most of the mints may be found in blossom in August.

The name mint is also applied to plants of other genera, *Monarda punctata* being called Horsemint, *Pycnanthemum linifolium*, Mountain Mint, and *Nepeta Cataria*, Catmint.

MINTO, Sir Gilbert Elliot, First Earl of (1751–1814), was descended from an old border family, the Elliots of Minto, and was born at Edinburgh, April 23, 1751. His father, Sir Gilbert Elliot, was a member of the administration of Pitt and Grenville, and is spoken of by Horace Walpole as "one of the ablest men in the House of Commons." Young Elliot was educated by a private tutor, with whom at the age of twelve he went to Paris, where David Hume, who was then secretary of the embassy, undertook, from friendship to his father, the special charge of superintending his studies. After spending the winters of 1766 and 1767 at Edinburgh University, Elliot entered Oxford. On quitting the university he became a member of Lincoln's Inn, and was in 1774 called to the bar. He entered parliament in 1776, the year of his father's death. Although he gave a general support to Lord North's administration, he from the beginning occupied an independent position, and in 1782 supported the address of the Commons against an offensive war with America. From this time he became a declared follower of Fox and Burke, with the latter of whom he gradually came to be on terms of great intimacy. He was created Baron Minto in 1797, and after filling several diplomatic posts with great success became in 1807 governor-general of India. The character and events of his rule in India are described in vol. xii. p. 805. He was created Earl of Minto and Viscount Melgund in 1813. He returned to England in 1814, and died on June 21st of that year.

See *Life and Letters of Sir Gilbert Elliot, first Earl of Minto, from* 1751 *to* 1806, 1874; and *Life and Letters*, 1807–14, 1880. See also Mirabeau.

MINUCIUS FELIX, Marcus, one of the earliest, if not the earliest, of the Latin apologists for Christianity. Of his personal history nothing is known, and even the date at which he wrote can be only approximately ascertained. Jerome (*De Vir. Ill.*, 58) speaks of him as "Romæ insignis causidicus," but in this he is probably only improving on the expression of Lactantius (*Inst. Div.*, v. 1) who speaks of him as "non ignobilis inter causidicos loci." He is now exclusively known by his *Octavius*, a dialogue on Christianity between the pagan Cæcilius Natalis[1] and the Christian Octavius Januarius, a provincial solicitor, the friend and fellow-student of the author. The scene is pleasantly and graphically laid on the beach at Ostia on a holiday afternoon, and the discussion is represented as arising out of the homage paid by Cæcilius, in passing, to the image of Serapis. His arguments for paganism, which proceed partly upon agnostic grounds, partly upon the inexpediency of disturbing long-established religious beliefs, partly upon the known want of culture in Christians, the alleged indecency of their worship, and the inherent absurdity of their doctrines, are taken up seriatim by Octavius, with the result that the assailant is convinced, postponing, however, the discussion of some things necessary for perfect instruction to a future occasion. The form of the dialogue, modelled on the *De Natura Deorum* and *De Divinatione* of Cicero, shows much care and ability, and its style is on the whole both vigorous and elegant if at times not exempt from something of the affectations of the age. If the doctrines of the Divine unity, the resurrection, and future rewards and punishments be left out of account, the work has less the character of an exposition of Christianity than of a philosophical and ethical polemic against the absurdities of crass polytheism. Christology and the other metaphysics of distinctively Christian theology are entirely passed over, and the canonical Scriptures are not quoted, hardly even alluded to.

The *Octavius* is admittedly earlier than Cyprian's *De Idolorum Vanitate*, which borrows from it; how much earlier can be determined only by settling the relation in which it stands to Tertullian's *Apologeticum*. The argument for the priority of Minucius has been most exhaustively set forth by Ebert ("Tertullians Verhältniss zu Minucius Felix," in vol. v. of the philologico-historical series in *Abhandl. d. König. Sächs. Gesellsch. der Wissenschaften*, 1868), who has been followed by Teuffel (*Röm. Lit.*, sec. 368), Keim (*Celsus' Wahres Wort*, 1873), Kuhn, and other scholars. The opposite view is ably maintained by Professor Salmon ("Minucius Felix" in Smith's *Dict. Christ. Biogr.*, 1882). The *Octavius* was first printed (Rome, 1543) as the eighth book of Arnobius *Adv. Gentes*; Balduinus (Heidelberg, 1560) first assigned it to its proper author. There have been numerous subsequent editions, the best being that of Halm in the *Corp. Scriptor. Eccl. Lat.* (Vienna, 1867). See Kuhn's monograph, *Der Octavius des Minucius Felix* (1882).

MINUET (Fr. *Menuet*, from [*pas*] *menus*), a very graceful kind of dance, consisting of a coupee, a high step, and a balance. Its invention is universally ascribed to the inhabitants of Poitou. The melody begins with the down beat, and contains three crotchets in a bar. The music is made up of two strains, which, from being repeated, are called *reprises*, each consisting of eight or more bars, but very rarely of an odd number. Walther speaks of a minuet in Lully's opera of *Roland*, each strain of which contains ten bars, the sectional number being five,—a circumstance which renders it very difficult to be danced; but Lully's system of phrasing was remarkably irregular. Modern instrumental composers have introduced into their symphonies and quartetts, &c., minuets of rapid movement and fanciful character, followed by supplementary strains (called trios) in a different style. Some of these compositions bear but very slight resemblance to the older forms; and many of them begin with the third beat in the bar. The finest minuets we possess are those in Handel's *Samson* and Mozart's *Don Giovanni*.

MIRABEAU, Honoré Gabriel Riqueti, Comte de, (1749–1791), one of the greatest statesmen and orators

[1] This name occurs in six inscriptions of the years 211–217 found at Constantine (Cirta), North Africa (*C. I. L.*, vol. viii.).

France has ever produced, was born at Bignon, near Nemours, on March 9, 1749. M. de Loménie has shown that the family of Riquet or Riqueti came originally from the little town of Digne, that they won wealth and municipal honours as merchants at Marseilles, and that in 1570 Jean Riqueti bought the chateau and estate of Mirabeau, which had up to that time belonged to the great Provençal family of Barras, and took the title of esquire a few years later. In 1685 Honoré Riqueti obtained the title of Marquis de Mirabeau, and his son Jean Antoine brought honour to it. He served with distinction through all the later campaigns of the reign of Louis XIV., and especially distinguished himself in 1705 at the battle of Cassano, where he was so severely wounded in the neck that he had ever after to wear a silver stock; yet he never rose above the rank of colonel, owing to his eccentric habit of speaking unpleasant truths to his superiors. On retiring from the service he married Françoise de Castellane, a remarkable woman, who long survived him, and he left at his death, in 1737, three sons —Victor, Marquis de Mirabeau (see next article), Jean Antoine, Bailli de Mirabeau, and Comte Louis Alexandre de Mirabeau. The great Mirabeau was the elder surviving son of the marquis. When but three years old he had a virulent attack of confluent small-pox which left his face for ever disfigured, and contributed not a little to nourish his father's dislike to him. His early education was conducted by Lachabeaussière, father of the better known man of letters, after which, being like his father and grandfather destined for the army, then the only profession open to young men of family, he was entered at a pension militaire at Paris, kept by an Abbé Choquart. Of this school, which had Lagrange for its professor of mathematics, we have an amusing account in the life of Gilbert Elliot, first earl of Minto, who with his brother Hugh, afterwards British minister at Berlin, there made the acquaintance of Mirabeau, an acquaintance which soon ripened into friendship, and to which Mirabeau in later life owed his introduction into good English society. On leaving this school in 1767 he received a commission in the cavalry regiment of the Marquis de Lambert, which his grandfather had commanded years before. He at once began love making, and in spite of his ugliness succeeded in winning the heart of the lady to whom his colonel was attached, which led to such scandal that his father obtained a lettre de cachet, and the young scapegrace was imprisoned in the isle of Rhé. The love affairs of Mirabeau form quite a history by themselves, and a well-known history, owing to the celebrity of the letters to Sophie; and the behaviour of the marquis in perpetually imprisoning his son is equally well known, and as widely blamed. Yet it may be asserted that until the more durable and more reputable connexion with Madame de Nehra these love episodes were the most disgraceful blemishes in a life otherwise of a far higher moral character than has been commonly supposed. As to the marquis, his use of lettres de cachet is perfectly defensible on the theory of the existence of lettres de cachet at all. They were meant to be used (see Lettres de Cachet) by heads of families for the correction of their families, and Mirabeau, if any son, surely deserved such correction. Further, they did have the effect of sobering the culprit, and the more creditable part of his life did not begin till he left Vincennes. Mirabeau, it may be remarked at once, was not a statesman of the Alcibiades type, and he did not develop his great qualities of mind and character until his youthful excesses were over. These will be passed over as rapidly as possible, for it was not till 1781 that the qualities which made him great began to appear.

On being released from his first imprisonment, the young count, who had always intended to continue his military career, obtained leave to accompany as a volunteer the French expedition which was to effect the reduction of Corsica. The conquest was one of sheer numerical strength, for the whole population was on the side of Paoli, and Mirabeau, perceiving the value of public opinion, is said to have written a treatise on the oppression the Genoese had formerly exercised over the island, which the Government was ready to publish had not the Marquis de Mirabeau thought fit to destroy it because of its divergence from his own philosophical and economical views. For his services in Corsica Mirabeau was made a captain of dragoons, though not in any particular regiment, and on his return his father endeavoured to make use of the literary ability he had shown for the advancement of his own economical theories. He tried to keep on good terms with his father, though he could not advocate all his ideas, and even went so far in 1772 as to marry a rich heiress, a daughter of the Marquis de Marignane, whose alliance his father had procured for him. He did not live happily with her, and in 1774 was ordered into semi-exile in the country, at his father's request, where he wrote his earliest extant work, the *Essai sur le Despotisme*. His violent disposition now led him to quarrel with a country gentleman who had insulted his sister, and his semi-exile was changed by lettre de cachet into imprisonment in the Chateau d'If. In 1775 he was removed to the castle of Joux, to which, however, he was not very closely confined, having full leave to visit in the town of Pontarlier. Here he met Marie Therèse de Monnier, his Sophie as he called her, a married woman, for whom he conceived a violent passion. Of his behaviour nothing too strong can be said: he was introduced into the house as a friend, and betrayed his trust by inducing Madame de Monnier to fall in love with him, and all his excuses about overwhelming passion only make his conduct more despicable. The affair ended by his escaping to Switzerland, where Sophie joined him; they then went to Holland, where he lived by hack-work for the booksellers; meanwhile Mirabeau had been condemned to death at Pontarlier for *rapt et vol*, of which he was certainly not guilty, as Sophie had followed him of her own accord, and in May 1777 he was seized by the French police, and imprisoned by a lettre de cachet in the castle of Vincennes. There he remained three years and a half, and with his release ends the first and most disgraceful period of his life. During his imprisonment he seems to have learnt to control his passions from their very exhaustion, for the early part of his confinement is marked by the indecent letters to Sophie (first published in 1793), and the obscene *Erotica Biblion* and *Ma Conversion*, while to the later months belongs his first political work of any value, the *Lettres de Cachet*. The *Essai sur le Despotisme* was an ordinary but at times eloquent declamation, showing in its illustrations a wide miscellaneous knowledge of history, but the *Lettres de Cachet* exhibits a more accurate knowledge of French constitutional history skilfully applied to an attempt to show that an existing actual grievance was not only philosophically unjust but constitutionally illegal. It shows, though still in rather a diffuse and declamatory form, that application of wide historical knowledge, keen philosophical perception, and genuine eloquence to a practical purpose which was the great characteristic of Mirabeau, both as a political thinker and as a statesman.

With his release from Vincennes begins the second period of Mirabeau's life. He found that his Sophie was an idealized version of a rather common and ill-educated woman, and she speedily consoled herself with the affection of a young officer, after whose death she committed suicide. Mirabeau first set to work to get the sentence of death still hanging over him reversed, and by his eloquence not only succeeded but got M. de Monnier condemned in the costs of

the whole law proceedings. From Pontarlier he went to Aix, where he claimed the court's order that his wife should return to him. She naturally objected, but his eloquence would have won his case, even against Portalis, the leader of the Aix bar, had he not in his excitement accused his wife of infidelity, on which the court pronounced a decree of separation. He then with his usual impetuosity intervened in the suit pending between his father and mother before the parlement of Paris, and so violently attacked the ruling powers that he had to leave France and again go to Holland, and try to live by literary work. About this time began his connexion with Madame de Nehra, which sweetened the ensuing years of toil and brought out the better points of his character. She was the daughter of Zwier van Haren, a Dutch statesman and political writer, and was a woman of a far higher type than Sophie, more educated, more refined, and more capable of appreciating Mirabeau's good points and helping him to control his passions. With her the lion became a lamb, and his life was strengthened by the love of his *petite horde*, Madame de Nehra, her baby son, afterwards Lucas de Montigny, and his little dog Chico. After a period of work in Holland he betook himself to England, where his treatise on *Lettres de Cachet* had been much admired, and where he was soon admitted into the best Whig literary and political society of London, through his old schoolfellow Gilbert Elliot, who had now inherited his father's baronetcy and estates, and become a leading Whig member of parliament. Sir Gilbert introduced him freely, but of all his English friends none seem to have been so intimate with him as Lord Lansdowne, and Mr (afterwards Sir Samuel) Romilly. The latter became particularly attached to him, and really understood his character; and it is strange that his remarks upon Mirabeau in the fragment of autobiography which he left, and Mirabeau's letters to him, should have been neglected by French writers. Romilly was introduced to Mirabeau by D'Ivernois, and readily undertook to translate the *Considerations on the Order of Cincinnatus*. Romilly writes thus of him in his autobiography:—

"The count was difficult enough to please; he was sufficiently impressed with the beauties of the original. He went over every part of the translation with me, observed on every passage in which justice was not done to the thought or the force of the expression lost, and made many useful criticisms. During this occupation we had occasion to see one another often, and became very intimate; and, as he had read much, had seen a great deal of the world, was acquainted with all the most distinguished persons who at that time adorned either the royal court or the republic of letters in France, had a great knowledge of French and Italian literature, and possessed very good taste, his conversation was extremely interesting and not a little instructive. I had such frequent opportunities of seeing him at this time, and afterwards at a much more important period of his life, that I think his character was well known to me. I doubt whether it has been so well known to the world, and I am convinced that great injustice has been done him. This, indeed, is not surprising, when one considers that, from the first moment of his entering upon the career of an author, he had been altogether indifferent how numerous or how powerful might be the enemies he should provoke. His vanity was certainly excessive; but I have no doubt that, in his public conduct as well as in his writings, he was desirous of doing good, that his ambition was of the noblest kind, and that he proposed to himself the noblest ends. He was, however, like many of his countrymen, who were active in the calamitous Revolution which afterwards took place, not sufficiently scrupulous about the means by which those ends were to be accomplished. He indeed to some degree professed this; and more than once I have heard him say that there were occasions upon which 'la petite morale était ennemie de la grande.' It is not surprising that with such maxims as these in his mouth, unguarded in his expressions, and careless of his reputation, he should have afforded room for the circulation of many stories to his disadvantage. Violent, impetuous, conscious of the superiority of his talents, and the declared enemy and denouncer of every species of tyranny and oppression, he could not fail to shock the prejudices, to oppose the interests, to excite the jealousy, and to wound the pride of many descriptions of persons. A mode of refuting his works, open to the basest and vilest of mankind, was to represent him as a monster of vice and profligacy. A scandal once set on foot is strengthened and propagated by many, who have no malice against the object of it. They delight to talk of what is extraordinary; and what more extraordinary than a person so admirable for his talents and so contemptible for his conduct, professing in his writings principles so excellent and in all the offices of public and private life putting in practice those which are so detestable? I indeed possessed demonstrative evidence of the falsehood of some of the anecdotes which by men of high character were related to his prejudice."—*Life of Sir S. Romilly*, vol. i. p. 58.

This luminous judgment, the best that is extant on the character of Mirabeau, deserved to be quoted at length; it must be noted that it was written by a man of acknowledged purity of life, who admired Mirabeau in early life, not when he was a statesman, but when he was only a struggling literary man. This close association with Romilly, and his friends Baynes, Trail, and Wilson, does credit to Mirabeau, and must have helped that moral revolution against his passions which was passing within him. He was a warm friend, and first made Romilly acquainted with Lord Lansdowne, and tried to get him a seat in parliament. Lord Lansdowne was himself an extraordinary man, and the first of the new Whigs might well feel sympathy with the statesman of the French Revolution. The *Considérations sur l'ordre de Cincinnatus* which Romilly translated was the only important work Mirabeau wrote in the year 1785, and it is a good specimen of his method. He had read a pamphlet published in America attacking the proposed order, which was to form a bond of association between the officers who had fought in the American War of Independence against England; the arguments struck him as true and valuable, so he rearranged them in his own fashion, and rewrote them in his own oratorical style. He soon found such work not sufficiently remunerative to keep his "petite horde" in comfort, and then turned his thoughts to employment from the French foreign office either in writing or in diplomacy. He first sent Madame de Nehra to Paris to make his peace with the authorities, in which she was completely successful, and then returned himself, hoping to get employment through an old literary collaborateur of his, Durival, who was at this time director of the finances of the department of foreign affairs. One of the functions of this official was to subsidize political pamphleteers, and Mirabeau had hoped to be so employed, but he ruined his chances by a series of financial works. On his return to Paris he had become acquainted with Clavières, a Genevese exile, who was minister of finance during the Revolution, and who now introduced him to a banker named Panchaud. From them he heard plenty of abuse of stock-jobbing, and seizing their ideas he began to regard stock-jobbing, or agiotage, as the source of all evil, and to attack in his usual vehement style the Banque de St Charles and the Compagnie des Eaux. This was at least disinterested on his part, for, while his supporters were poor, the bankers he attacked were rich, and would gladly have bought his silence; but Mirabeau, though ever ready to take money for what he wrote, never sold his opinions, or wrote what he did not really believe. The very eloquence of his style rests upon the enthusiastic conviction that he himself was right, and those who differed from him were stupidly and wilfully wrong. This last pamphlet brought him into a controversy with Beaumarchais, who certainly did not get the best of it, but it lost him any chance of literary employment from Government. However, his ability was too great to be neglected by a great minister such as M. de Vergennes undoubtedly was, and after a preliminary tour in the early spring of 1786 he was despatched in June 1786 on a secret mission to the court of Prussia, from which he returned in January 1787, and of which he gave a full account in his *Histoire Secrète de la Cour de Berlin*.

The months he spent at Berlin were important ones in the history of Prussia, for in them Frederick the Great died. The letters just mentioned show clearly what Mirabeau did and what he saw, and equally clearly how unfit he was to be a diplomatist; for, with all his knowledge of men and his influence over them, he thought (and showed he thought) too much of himself ever to be able to surprise their secret thoughts and intentions. He certainly failed to conciliate the new king Frederick William; and thus ended Mirabeau's one attempt at diplomacy. During his journey he had made the acquaintance of a Major Mauvillon, whom he found possessed of a great number of facts and statistics with regard to Prussia; these he made use of in a great work on Prussia published in 1788, as Romilly says, to show that he could write more than a fugitive pamphlet. But, though his *Monarchie Prussienne* gave him a general reputation for historical learning, he had in this same year lost a chance of political employment. He had offered himself as a candidate for the office of secretary to the Assembly of Notables which the king had just convened, and to bring his name before the public published another financial work, the *Denonciation de l'Agiotage*, dedicated to the king and notables, which abounded in such violent diatribes that he not only lost his election, but was obliged to retire to Tongres; and he further injured his prospects by publishing the reports he had sent in during his secret mission at Berlin. But 1789 was at hand; the states-general was summoned; Mirabeau's period of probation was over, and he was at last to have that opportunity of showing his great qualities both as statesman and orator on a worthy arena.

On hearing of the king's determination to summon the states-general, Mirabeau started for Provence, and offered to assist at the preliminary conference of the noblesse of his district. They rejected him; he appealed to the *tiers état*, and was returned both for Aix and for Marseilles. He elected to sit for the former city, and was present at the opening of the states-general on May 4, 1789. From this time the record of Mirabeau's life forms the best history of the first two years of the Constituent Assembly, for at every important crisis his voice is to be heard, though his advice was not always followed. It is impossible here to detail minutely the history of these two eventful years; it will be rather advisable to try and analyse the manner in which Mirabeau regarded passing events, and then show how his policy justifies our analysis.

Mirabeau possessed at the same time great logical acuteness and most passionate enthusiasm; he was therefore both a statesman and an orator, and the interest of the last two years of his life lies mainly in the gradual but decided victory of the statesmanlike and practical over the impulsive and oratorical qualities. From the beginning Mirabeau recognized that government exists in order that the bulk of the population may pursue their daily work in peace and quiet, and that for a Government to be successful it must be strong. In this practical view of the need of a strong executive lies one of Mirabeau's greatest titles to the name of statesman. At the same time he thoroughly comprehended that for a Government to be strong it must be in harmony with the wishes of the majority of the people, and that the political system of Louis XIV. was now falling for lack of this. He had carefully studied the English constitution in England under the guidance of such men as Lord Lansdowne, Sir Gilbert Elliot, and Romilly, and appreciated it with the wise approval of its powers of expansion which characterized the new Whigs, and not with the blind admiration of Burke. He understood the key-notes of the practical success of the English constitution to be the irresponsibility of the king, the solidarity of the ministers, and the selection of the executive from among the majority of the representatives of the country; and he hoped to establish in France a system similar in principle, but without any slavish imitation of the details of the English constitution.

In the first stage of the history of the states-general Mirabeau's part was very great. He was soon recognized as a leader, to the chagrin of Mounier, because he always knew his own mind, and was prompt at emergencies. To him is to be attributed the successful consolidation of the National Assembly, its continuance in spite of De Brezé and the carpenters, and the address to the king for the withdrawal of the troops assembled by De Broglie. When the taking of the Bastille had assured the success of the Revolution, he was the one man who warned the Assembly of the futility of passing fine-sounding decrees and the necessity for acting. He declared that the famous night of August 4 was but an orgy, giving the people an immense theoretical liberty while not assisting them to practical freedom, and overthrowing the old régime before a new one could be constituted. Still more did he show his foresight when he attacked the dilatory behaviour of the Assembly, which led to the catastrophes of the 5th and 6th October. He implored the Assembly to strike while the iron was hot, and at once solve in a practical manner the difficult problems presented by the abolition of feudalism. But the Assembly consisted of men inexperienced in practical politics, who dreamed of drawing up an ideal constitution preluded by a declaration of rights in imitation of the Americans; and for two months the Assembly discussed in what words the declaration should be expressed, while the country was in a state of anarchy, declaring old laws and customs abolished and having no new ones to obey or follow, disowning the old administrative system and having no new one yet instituted, while Paris was starving and turbulent, and the queen and her friends planning a counter-revolution. The result of these two months' theorizing was the march of the women to Versailles, and the transfer of the king to Paris. Mirabeau now saw clearly that his eloquence would not enable him to guide the Assembly by himself, and that he must therefore try to get some support. He wished to establish a strong ministry, which should be responsible like an English ministry, but to an assembly chosen to represent the people of France better than the English House of Commons then represented England. He first thought of becoming a minister at a very early date, if we may believe a story contained in the *Mémoires* of the Duchesse d'Abrantes, to the effect that in May 1789 the queen tried to bribe him, but that he refused to be bribed to silence, and expressed his wish to be a minister. The indignation with which the queen repelled the idea may have been the cause of his thinking of the Duc d'Orleans as a possible constitutional king, because his title would of necessity be parliamentary. But the weakness of Orleans was too palpable, and in a famous remark Mirabeau expressed his utter contempt for him. He also attempted to form an alliance with Lafayette, but the general was as vain and as obstinate as Mirabeau himself, and had his own theories about a new French constitution. Mirabeau tried for a time, too, to act with Necker, and obtained the sanction of the Assembly to Necker's financial scheme, not because it was good, but because, as he said, "no other plan was before them, and something must be done."

Hitherto weight has been laid on the practical side of Mirabeau's political genius; his ideas with regard to the Revolution after the 5th and 6th October must now be examined, and this can be done at length, thanks to the publication of Mirabeau's correspondence with La Marck, a study of which is indispensable for any correct knowledge of the history of the Revolution between 1789 and 1791.

The Comte de la Marck was a Flemish lord of the house of Aremberg, who had been proprietary colonel of a regiment in the service of France; he was a close friend of the queen, and had been elected a member of the states-general. His acquaintance with Mirabeau, commenced in 1788, ripened during the following year into a friendship, which La Marck hoped to turn to the advantage of the court. After the events of the 5th and 6th of October he consulted Mirabeau as to what measures the king ought to take, and Mirabeau, delighted at the opportunity, drew up an admirable state-paper, which was presented to the king by Monsieur, afterwards Louis XVIII. The whole of this *Mémoire* should be read to get an adequate idea of Mirabeau's genius for politics; here it must be merely summarized.

The main position is that the king is not free in Paris; he must therefore leave Paris and appeal to France. "Paris n'en veut que l'argent; les provinces demandent des lois." But where must the king go? "Se retirer à Metz ou sur toute autre frontière serait déclarer la guerre à la nation et abdiquer le trône. Un roi qui est la seule sauvegarde de son peuple ne fuit point devant son peuple; il le prend pour juge de sa conduite et de ses principes." He must then go towards the interior of France to a provincial capital, best of all to Rouen, and there he must appeal to the people and summon a great convention. It would be ruin to appeal to the noblesse, as the queen advised: "un corps de noblesse n'est point une armée, qui puisse combattre." When this great convention met, the king must show himself ready to recognize that great changes have taken place, that feudalism and absolutism have for ever disappeared, and that a new relation between king and people has arisen, which must be loyally observed on both sides for the future. "Il est certain, d'ailleurs, qu'il faut une grande révolution pour sauver le royaume, que la nation a des droits, qu'elle est en chemin de les recouvrer tous, et qu'il faut non seulement les rétablir, mais les consolider." To establish this new constitutional position between king and people would not be difficult, because "l'indivisibilité du monarque et du peuple est dans le cœur de tous les Français; il faut qu'elle existe dans l'action et le pouvoir."

Such was Mirabeau's programme, which he never diverged from, but which was far too statesmanlike to be understood by the poor king, and far too positive as to the altered condition of the monarchy to be palatable to the queen. Mirabeau followed up his *Mémoire* by a scheme of a great ministry to contain all men of mark,—Necker as prime minister, "to render him as powerless as he is incapable, and yet preserve his popularity for the king," the archbishop of Bordeaux, the Duc de Liancourt, the Duc de la Rochefoucauld, La Marck, Talleyrand bishop of Autun at the finances, Mirabeau without portfolio, Target mayor of Paris, Lafayette generalissimo to reform the army, Ségur (foreign affairs), Mounier, and Chapelier. This scheme got noised abroad, and was ruined by a decree of the Assembly of November 7, 1789, that no member of the Assembly could become a minister; this decree destroyed any chance of that necessary harmony between the ministry and the majority of the representatives of the nation existing in England, and so at once overthrew Mirabeau's present hopes and any chance of the permanence of the constitution then being devised. The queen utterly refused to take Mirabeau's counsel, and La Marck left Paris. However, in April 1790 he was suddenly recalled by the Comte de Mercy-Argenteau, the Austrian ambassador at Paris, and the queen's most trusted political adviser, and from this time to Mirabeau's death he became the medium of almost daily communications between the latter and the queen. Mirabeau at first attempted again to make an alliance with Lafayette by a letter in which he says, "Les Barnave, les Duport, les Lameth ne vous fatiguent plus de leur active inaction; on singe longtemps l'adresse, non pas la force." But it was useless to appeal to Lafayette; he was not a strong man himself, and did not appreciate "la force" in others. From the month of May 1790 to his death in April 1791 Mirabeau remained in close and suspected but not actually proved connexion with the court, and drew up many admirable state-papers for it. In return the court paid his debts; but it ought never to be said that he was bribed, for the gold of the court never made him swerve from his political principles—never, for instance, made him a royalist. He regarded himself as a minister, though an unavowed one, and believed himself worthy of his hire. Undoubtedly his character would have been more admirable if he had acted without court assistance, but it must be remembered that his services deserved some reward, and that by remaining at Paris as a politician he had been unable to realize his paternal inheritance. Before his influence on foreign policy is discussed, his behaviour on several important points must be noticed. On the great question of the veto he took a practical view, and seeing that the royal power was already sufficiently weakened, declared for the king's absolute veto, and against the compromise of the suspensive veto. He knew from his English experiences that such a veto would be hardly ever used unless the king felt the people were on his side, in which case it would be a useful check on the representatives of the people, and also that if it was used unjustifiably the power of the purse possessed by the representatives and the very constitutional organization of the people would, as in England in 1688, bring about a bloodless revolution, and a change in the person entrusted with the royal dignity. He saw also that much of the inefficiency of the Assembly arose from the inexperience of the members, and their incurable verbosity; so, to establish some system of rules, he got his friend Romilly to draw up a detailed account of the rules and customs of the English House of Commons, which he translated into French, but which the Assembly, puffed up by a belief in its own merits, refused to use. On the great subject of peace and war he supported the king's authority, and with some success. What was the good of an executive which had no power? Let it be responsible to the representatives of the nation by all means; but if the representatives absorbed all executive power by perpetual interference, there would be six hundred kings of France instead of one, which would hardly be a change for the better. Again Mirabeau almost alone of the Assembly understood the position of the army under a limited monarchy. Contrary to the theorists, he held that the soldier ceased to be a citizen when he became a soldier; he must submit to be deprived of his liberty to think and act, and must recognize that a soldier's first duty is obedience. With such sentiments, it is no wonder that he approved of Bouillé's vigorous conduct at Nancy, which was the more to his credit as Bouillé was the one hope of the court influences opposed to him. Lastly, in matters of finance he showed his wisdom: he attacked Necker's "caisse d'escompte," which was to have the whole control of the taxes, as absorbing the Assembly's power of the purse; and he heartily approved of the system of assignats, but with the important reservation that they should not be issued to the extent of more than one-half the value of the lands to be sold. This restriction was not observed, and it was solely the enormous over-issue of assignats that caused their great depreciation in value.

Of Mirabeau's attitude with regard to foreign affairs it is necessary to speak in more detail. He held it to be just that the French people should conduct their Revolution as they would, and that no foreign nation had any right to interfere with them, so long as they kept themselves strictly to their own affairs. But he knew also that neighbouring nations looked with unquiet eyes on the progress of affairs in France, that they feared the influence of the Revolution on their own peoples, and that foreign monarchs were being prayed by the French emigrés to interfere on behalf of the French monarchy. To prevent this interference, or rather to give no pretext for it, was his guiding thought as

to foreign policy. He had been elected a member of the comité diplomatique of the Assembly in July 1790, and became its reporter at once, and in this capacity he was able to prevent the Assembly from doing much harm in regard to foreign affairs. He had long known Montmorin, the foreign secretary, and, as matters became more strained from the complications with the princes and counts of the empire, he entered into daily communication with the minister, advised him on every point, and, while dictating his policy, defended it in the Assembly. Thus in this particular instance of the foreign office, for the few months before Mirabeau's death, a harmony was established between the minister and the Assembly through Mirabeau, which checked for a time the threatened approach of foreign intervention, and maintained the honour of France abroad. Mirabeau's exertions in this respect are not his smallest title to the name of statesman; and how great a work he did is best proved by the confusion which ensued in this department of affairs upon his death.

For indeed in the beginning of 1791 his death was very near; and he knew it to be so. The wild excesses of his youth and their terrible punishment had weakened his strong constitution, and his parliamentary labours completed the work. So surely did he feel its approach that some time before the end he sent all his papers over to his old English friend and schoolfellow Sir Gilbert Elliot, who kept them under seal until claimed by Mirabeau's executors. In March his illness was evidently gaining on him, to his great grief, because he knew how much depended on his life, and felt that he alone could yet save France from the distrust of her monarch and the present reforms, and from the foreign interference, which would assuredly bring about catastrophes unparalleled in the history of the world. On his life hung the future course of the Revolution. Every care that science could afford was given by his friend and physician, the famous chemist Cabanis, to whose brochure on his last illness and death the reader may refer. The people, whose faith in him revived in spite of all suspicions, when they heard that he was on his death-bed, kept the street in which he lay quiet; but medical care, the loving solicitude of friends, and the respect of all the people could not save his life. His vanity appears in its most gigantic proportions in his last utterances during his illness; but many of them have something grand in their sound, as his last reported expression, when he looked upon the sun—"If he is not God, he is at least His cousin-german." When he could speak no more he wrote with a feeble hand the one word "dormir," and on April 2, 1791, he died.

With Mirabeau died, it has been said, the last hope of the monarchy; but, with Marie Antoinette supreme at court, can it be said that there could ever have been any real hope for the monarchy? Had she been but less like her imperious mother, Louis would have made a constitutional monarch, but her will was as strong as Mirabeau's own, and the Bourbon monarchy had to meet its fate. The subsequent events of the Revolution justified Mirabeau's prognostications in his first mémoire of October 15, 1789. The royal family fled towards the German frontier, and from that moment there sunk deep into the hearts of the people not only of Paris, but of the provinces, a conviction that the king and queen were traitors to France, which led inevitably to their execution. The noblesse and the foreign aid on which the queen relied proved but a source of weakness. The noblesse, Mirabeau had said, was no army which could fight; and truly the army of the emigrés could do nothing against revolutionary France in arms. The intervention of foreign aid only sealed the king's fate, and forwarded the progress of the Revolution, not in a course of natural development, but to the terrible resource of the Reign of Terror. With regard to the Assembly too, and its constitution, Mirabeau had shown his foresight. The constitution of 1791, excellent as it was on paper, and well adapted to an ideal state, did not deal adequately with the great problems of the time in France, and by its ridiculous weakening of the executive was unsuited to a modern state. Surely if events ever proved a man's political sagacity, the history of the French Revolution proved Mirabeau's.

A few words must be added on Mirabeau's manner of work and his character.

No man ever so thoroughly used other men's work, and yet made it all seem his own. "Je prends mon bien où je le trouve" is as true of him as of Molière. His first literary work, except the bombastic but eloquent *Essai sur le Despotisme*, was a translation of Watson's *Philip II.*, accomplished in Holland with the help of Durival; his *Considérations sur l'ordre de Cincinnatus* was based on an American pamphlet, and the notes to it were contributed by Target; while his financial writings were all suggested by the Genevese exile Clavières. During the Revolution he received yet more help; men were proud to labour for him, and did not murmur because he absorbed all the credit and fame. Dumont, Clavières, Duroveray, Pellenc, Lamourette, and Reybaz were but a few of the most distinguished of his collaborators. Dumont was a Genevese exile, and an old friend of Romilly's, who willingly prepared for him those famous addresses which Mirabeau used to make the Assembly pass by sudden bursts of eloquent declamation; Clavières and Duroveray helped him in finance, and not only worked out his figures, but even wrote his financial discourses. Pellenc was his secretary, and wrote the speeches on the goods of the clergy and the right of making peace, and even the Abbé Lamourette wrote the speeches on the civil constitution of the clergy. Reybaz, whose personality has only been revealed within these last ten years, not only wrote for him his famous speeches on the assignats, the organization of the national guard, &c., which Mirabeau read word for word at the tribune, but even the posthumous speech on succession to estates of intestates, which Talleyrand read in the Assembly as the last work of his dead friend. Yet neither the gold of the court nor another man's conviction would make Mirabeau say what he did not himself believe, or do what he did not himself think right. He took other men's labour as his due, and impressed their words, of which he had suggested the underlying ideas, with the stamp of his own individuality; his collaborators themselves did not complain,—they were but too glad to be of help in the great work of controlling and forwarding the French Revolution through its greatest thinker and orator. True is that remark of Goethe's to Eckermann, after reading Dumont's *Souvenirs*: "At last the wonderful Mirabeau becomes natural to us, while at the same time the hero loses nothing of his greatness. Some French journalists think differently. . . . . The French look upon Mirabeau as their Hercules, and they are perfectly right. But they forget that even the Colossus consists of individual parts, and that the Hercules of antiquity is a collective being—a gigantic personification of deeds done by himself and by others."

There was something gigantic about all Mirabeau's thoughts and deeds. The excesses of his youth were beyond all bounds, and severely were they punished; his vanity was immense, but never spoilt his judgment; his talents were enormous, but could yet make use of those of others. As a statesman his wisdom is indubitable, but by no means universally recognized in his own country. Lovers of the *ancien régime* abuse its most formidable and logical opponent; believers in the Constituent Assembly cannot be expected to care for the most redoubtable adversary of their favourite theorists, while admirers of the republic of every description agree in calling him from his connexion with the court the traitor Mirabeau. As an orator more justice has been done him: his eloquence has been likened to that of both Bossuet and Vergniaud, but it had neither the polish of the old 17th-century bishop nor the flashes of genius of the young Girondin. It was rather parliamentary oratory in which he excelled, and his true compeers are rather Burke and Fox than any French speakers. Personally he had that which is the truest mark of nobility of mind, a power of attracting love, and winning faithful friends. "I always loved him," writes Sir Gilbert Elliot to his brother Hugh; and Romilly, who was not given to lavish praise, says, "I have no doubt that in his public conduct, as in his writings, he was desirous of doing good, that his ambition was of the noblest kind, and that he proposed to himself the noblest ends." What more favourable judgment could be passed on an ambitious man! What finer epitaph could a statesman desire!

The best edition of Mirabeau's works is that published by Blanchard in 1822, in 10 vols., of which two contain his *Œuvres Oratoires*; from this collection, however, many of his less important works, and the *Monarchie Prussienne*, in 4 vols., 1788, are omitted. For his life consult *Mirabeau: Mémoires sur sa vie littéraire et privée*, 4 vols., 1824, and, what is of most importance, *Mémoires biographiques, littéraires, et politiques de Mirabeau écrits par lui-même, par son père, son oncle, et son fils adoptif*, which was issued by M. Lucas de Montigny in 8 vols., Paris, 1834. See also Dumont, *Souvenirs sur Mirabeau*, 1832; Duval, *Souvenirs sur Mirabeau*, 1832; Victor Hugo, *Étude sur Mirabeau*, 1834; *Mirabeau's Jugendleben*, Breslau, 1832; Schneidewin, *Mirabeau und seine Zeit*, Leipsic, 1831; *Mirabeau, a Life History*, London, 1848. The publication of the *Correspondance entre Mirabeau et le Comte de la Marck*, by Ad. Bacourt, 2 vols., 1851, marks an epoch in our exact knowledge of Mirabeau and his career. The most useful modern books are Louis de Loménie, *Les Mirabeau*, 1878, which, however, chiefly treats of his father and uncle; Ph. Plan, *Un Collaborateur de Mirabeau*, 1874, treating of Reybaz, and throwing infinite light on Mirabeau's mode of work; and, lastly, H. Reynald, *Mirabeau et la Constituante*, 1873. On his eloquence and the share his collaborators had in his speeches, see Aulard, *L'Assemblée Constituante*, 1882. For his death see the curious brochure of his physician Cabanis, *Journal de la maladie et de la mort de Mirabeau*, Paris, 1791. (H. M. S.)

MIRABEAU, VICTOR RIQUETI, MARQUIS DE (1715–1789), himself a distinguished author and political economist, but more famous as the father of the great Mirabeau, was born at Pertuis near the old chateau de Mirabeau on October 4, 1715. He was brought up very sternly by his father, and in 1729 joined the army. He took keenly to campaigning, but never rose above the rank of captain, owing to his being unable to get leave at court to buy a regiment. In 1737 he came into the family property on his father's death, and spent some pleasant years till 1743 in literary companionship with his dear friends Vauvenargues and Lefranc de Pompignan, which might have continued had he not suddenly determined to marry—not for money, but for landed estates. The lady whose property he fancied was Marie Geneviève, daughter of a M. de Vassan, a brigadier in the army, and widow of the Marquis de Saulvebœuf, whom he married without previously seeing her on April 21, 1743. While in garrison at Bordeaux, Mirabeau had made the acquaintance of Montesquieu, which may have made him turn his thoughts to political speculations; anyhow it was while at leisure after retiring from the army that he wrote his first work, his *Testament Politique* (1747), which demanded for the prosperity of France a return of the French noblesse to their old position in the Middle Ages. This work, written under the influence of the feudal ideas impressed upon him by his father, was followed in 1750 by a book on the *Utilité des États Provenciaux*, full of really wise considerations for local self-government, which was published anonymously, and had the honour of being attributed to Montesquieu himself. In 1756 Mirabeau made his first appearance as a political economist by the publication of his *Ami des Hommes ou traité de la population.* This work has been often attributed to the influence, and in part even to the pen, of Quesnay, the founder of the economical school of the physiocrats, but was really written before the marquis had made the acquaintance of the physician of Madame de Pompadour. In 1760 he published his *Théorie de l'Impôt,* in which he attacked with all the vehemence of his son the farmers-general of the taxes, who got him imprisoned for eight days at Vincennes, and then exiled to his country estate at Bignon. At Bignon the school of the physiocrats was really established, and the marquis surrounded himself with devotees, and eventually in 1765 bought the *Journal de l'agriculture, du commerce, et des finances,* which became the organ of the school. He was distinctly recognized as a leader of political thinkers by Prince Leopold of Tuscany, afterwards emperor, and by Gustavus III. of Sweden, who in 1772 sent him the grand cross of the order of Vasa. But the period of his happy literary life was over; and his name was to be mixed up in a long scandalous lawsuit. Naturally his marriage had not been happy; he had separated from his wife by mutual consent in 1762, and had, he believed, secured her safely in the provinces by a lettre de cachet, when in 1772 she suddenly appeared in Paris, and soon after commenced proceedings for a separation. The poor marquis did not know what to do; his sons were a great trouble to him, and it was one of his own daughters who had encouraged his wife to take this step. Yet he was determined to keep the case quiet if possible for the sake of Madame de Pailly, a Swiss lady whom he had loved since 1756. But his wife would not let him rest; her plea was rejected in 1777, but she renewed her suit, and, though the great Mirabeau had pleaded his father's case, was successful in 1781, when a decree of separation was pronounced. This trial had quite broken the health of the marquis, as well as his fortune; he sold his estate at Bignon, and hired a house at Argenteuil, where he lived quietly till his death on July 11, 1789.

For the whole family of Mirabeau, the one book to refer to is Louis de Loménie's *Les Mirabeau*, 2 vols., 1878, and it is greatly to be regretted that the talented author did not live to treat the lives of the great Mirabeau and his brother. See also Lucas de Montigny's *Mémoires de Mirabeau,* and, for the marquis's economical views, De la Vergne's *Économistes français du 18me siècle.*

MIRAGE. See LIGHT, vol. xiv. p. 600.

MIRAMON, MIGUEL, a Mexican soldier of French extraction, was born in the city of Mexico, September 29, 1832, and shot along with the emperor Maximilian at Queretaro, June 19, 1867. While still a student he helped to defend the military academy at Chapultepec against the forces of the United States; and, entering the army in 1852, he rapidly came to the front during the civil wars that disturbed the country. It was largely due to Miramon's support of the ecclesiastical party against Alvarez and Comonfort that Zuloaga was raised to the presidency; and in 1859 he was called to succeed him in that office. Decisively beaten, however, by the Liberals, he fled the country in 1860, and spent some time in Europe earnestly advocating foreign intervention in Mexican affairs; and when he returned it was as a partisan of Maximilian. His ability as a soldier was best shown by his double defence of Puebla in 1856.

MIRANDA, FRANCESCO (1754–1816), was born at Santa Fé in New Granada in 1754. He entered the army, and served against the English in the American War of Independence. The success of that war inspired him with a hope of being the Washington of his own country, and a belief that the independence of Spanish America would increase its material prosperity. With these views he began to scheme a revolution, but his schemes were discovered and he had only just time to escape to the United States. Thence he went to England, where he was introduced to Pitt, but chiefly lived with the leading members of the opposition—Fox, Sheridan, and Romilly. Finding no help in his revolutionary schemes, he travelled over the greater part of Europe, notably through Austria and Turkey, till he arrived at the court of Russia, where he was warmly received, but from which he was dismissed, though with rich presents, at the demand of the Spanish ambassador, backed up by the envoy of France. The news of the dispute between England and Spain about Nootka Sound in 1790 recalled him to England, where he saw a good deal of Pitt, who had determined to make use of him to "insurge" the Spanish colonies, but the peaceful arrangement of the dispute again destroyed his hopes. In April 1792 he went to Paris, with introductions to Pétion and the leading Girondists, hoping that men who were working so hard for their own freedom might help his countrymen in South America. France had too much to do in fighting for its own freedom to help others; but Miranda's friends sent him to the front with the rank of general of brigade. He distinguished himself under Dumouriez, was intrusted in February 1793 with the conduct of the siege of Maestricht, and commanded the left wing of the French army at the disastrous battle of Neerwinden. Although he had given notice of Dumouriez's projected treachery, he was put on his trial for treason on May 12. He was unanimously acquitted, but was soon again thrown into prison, and not released till after the 9th Thermidor. He again mingled in politics, and was sentenced to be deported after the struggle of Vendémiaire. Yet he escaped, and continued in Paris till the *coup d'état* of Fructidor caused him finally to take refuge in England. He now found Pitt and Dundas once more ready to listen to him, and the latter sent a special minute to Colonel Picton, the governor of Trinidad, to assist General Miranda's schemes in every possible way; but, as neither of them would or could give him substantial help, he went to the United States, where President Adams gave him fair words but nothing more. Once more he returned to England,

where Addington might have done something for him but for the signature of the peace of Amiens in 1802. At the peace, though in no way amnestied, he returned to Paris, but was promptly expelled by the First Consul, who was then eager to be on good terms with the court of Spain. Disappointed in further efforts to get assistance from England and the United States, he decided to make an attempt on his own responsibility and at his own expense. Aided by two American citizens, Colonel Smith and Mr Ogden, he equipped a small ship, the "Leander," in 1806, and with the help of the English admiral Sir A. Cochrane made a landing near Carácas, and proclaimed the Colombian republic. He had some success, and would have had more had not a false report of peace between France and England caused the English admiral to withdraw his support. At last in 1810 came his opportunity; the events in Spain which brought about the Peninsular War had divided the authorities in Spanish America, some of whom declared for Joseph Bonaparte, others for Ferdinand VII., while others again held to Charles IV. At this moment Miranda again landed, and had no difficulty in getting a large party together who declared a republic both in Venezuela and New Granada or Colombia. But Miranda's desire that all the South American colonies should rise, and a federal republic be formed, awoke the selfishness and pride of individual provincial administrations, and thus weakened the cause, which further was believed to be hateful to heaven owing to a great earthquake on March 26, 1812. The count of Monte Verde, the Bourbon governor, had little difficulty in defeating the dispirited forces of Miranda, and on July 26 the general capitulated on condition that he should be deported to the United States. The condition was not observed; Miranda was moved from dungeon to dungeon, and died in 1816 at Cadiz.

There are allusions to Miranda's early life in nearly all memoirs of the time, but they are not generally very accurate. For his trial see Buchez et Roux, *Histoire Parlementaire*, xxvii. 26–70. For his later life see Biggs, *History of Miranda's Attempt in South America*, London, 1809; and Veggasi, *Revolucion de la Columbia*.

MIRANDOLA. See Pico.

MIRKHOND (1433–1498). Mohammed bin Kháwandsháh bin Mahmúd, commonly called Mírkhwánd or Mírkháwand, more familiar to Europeans under the name of Mirkhond, was born in 1433, the son of a very pious and learned man who, although belonging to an old Bokhara family of Sayyids or direct descendants of the Prophet, lived and died in Balkh. From his early youth he applied himself to historical studies and literature in general. In Herát, where he spent the greater part of his life, he gained the favour of that famous patron of letters, Mír 'Alíshír (born 1440), who served his old school-fellow the reigning sultan Husain (who as the last of the Tímúrides in Persia ascended the throne of Herát in 1468), first as keeper of the seal, afterwards as governor of Jurján. At the request of this distinguished statesman and writer[1] Mirkhond began about 1474, in the quiet convent of Khilásíyah, which his patron had founded in Herát as a house of retreat for literary men of merit, his great work on universal history, the largest ever written in Persian, and to the present day an inexhaustible mine of information both to Eastern and Western scholars. It is named *Rauzat-ussafá fi sírat-ulanbiá walmulúk walkhulafá* or *Garden of Purity on the Biography of Prophets, Kings, and Caliphs*. That the author has made no attempt at a critical examination of historical traditions can scarcely be called a peculiar fault of his, since almost all Oriental writers are equally deficient in sound criticism; more censurable is his flowery and often bombastic style, but in spite of this drawback, and although, in our own age, the discovery of older works on Asiatic history has diminished to some extent the value of Mirkhond's *Rauzat*, it still maintains its high position as one of the most marvellous achievements in literature from the pen of one man, and often elucidates, by valuable text-corrections, various readings, and important additions, those sources which have lately come to light. It comprises seven large volumes and a geographical appendix; but internal evidence proves beyond doubt that the seventh volume, the history of the sultan Husain (1438–1505), together with a short account of some later events down to 1523, cannot have been written by Mirkhond himself, who died in 1498. He may have compiled the preface, but the main portion of this volume is probably the work of his grandson, the equally renowned historian Khwándamír (1475–1534), to whom also a part of the appendix must be ascribed.

The following is a summary of the contents of the other six volumes. Vol. i.: Preface on the usefulness of historical studies, history of the creation, the patriarchs, prophets, and rulers of Israel down to Christ, and the Persian kings from the mythical times of the Péshdádians to the Arab conquest and the death of the last Sásánian Yazdajird III. in 30 A.H. (651 A.D.). Vol. ii.: Mohammed, Abúbekr, 'Omar, 'Othmán, and 'Alí. Vol. iii.: The twelve imáms and the Omayyad and 'Abbásid caliphs down to 656 A.H. (1258 A.D.). Vol. iv.: The minor dynasties contemporary with and subsequent to the 'Abbásids, down to 778 A.H. (1376 A.D.), the date of the overthrow of the Kurds by Tímúr. Vol. v.: The Moghuls down to Tímúr's time. Vol. vi.: Tímúr and his successors down to Sultan Husain's accession in 873 A.H. (1468 A.D.). The best accounts of Mirkhond's life are De Sacy's "Notice sur Mirkhond" in his *Mémoires sur diverses antiquités de la Perse*, Paris, 1793; Jourdain's "Notice de l'histoire universelle de Mirkhond" in the *Notices et Extraits*, vol. ix., Paris, 1812 (together with a translation of the preface, the history of the Ismailians, the conclusion of the sixth volume, and a portion of the appendix); Elliot, *History of India*, vol. iv. p. 127 *sq.*; Morley, *Descriptive Catalogue*, London, 1854, p. 30 *sq.*; Rieu, *Cat. of Persian MSS. of the Brit. Mus.*, vol. i., London, 1879, p. 87 *sq.* Mirkhond's patron, Mír 'Alíshír, to whom the Rauzat is dedicated, died three years after him (1501).

Besides the lithographed editions of the whole work in folio, Bombay, 1853, and Teheran, 1852–56, and a Turkish version, Constantinople, 1842, the following portions of Mirkhond's history have been published by European Orientalists: *Early Kings of Persia*, by D. Shea, London, 1832 (Oriental Translation Fund); *L'Histoire de la dynastie des Sassanides*, by S. de Sacy (in the above-mentioned *Mémoires*); *Histoire des Sassanides* (*texte Persan*), by Jaubert, Paris, 1843; *Historia priorum regum Persarum*, Pers. and Lat., by Jenish, Vienna, 1782; *Mirchondi historia Taheridarum*, Pers. and Lat., by Mitscherlik, Göttingen, 1814, 2d ed., Berlin, 1819; *Historia Samanidarum*, Pers. and Lat., by Wilken, Göttingen, 1808; *Histoire des Samanides*, translated by Defrémery, Paris, 1845; *Historia Ghaznevidarum*, Pers. and Lat., by Wilken, Berlin, 1832; *Geschichte der Sultane aus dem Geschlechte Bujeh*, Pers. and German, by Wilken, Berlin, 1835; followed by Erdmann's *Erläuterung und Ergänzung*, Kazan, 1836; *Historia Seldschuckidarum*, ed. Vullers, Giessen, 1837, and a German translation by the same; *Histoire des Sultans du Kharezm*, in Persian, by Defrémery, Paris, 1842; *History of the Atabeks of Syria and Persia*, in Persian, by W. Morley, London, 1848; *Historia Ghuridarum*, Pers. and Lat., by Mitscherlik, Frankfort, 1818; *Histoire des Sultans Ghurides*, translated into French by Defrémery, Paris, 1844; *Vie de Djenghiz-Khan*, in Persian, by Jaubert, Paris, 1841 (see also extracts from the same 5th volume in French translation by Langlès in vol. vi. of *Notices et Extraits*, Paris, 1799, p. 192 *sq.*, and by Hammer in *Sur les origines Russes*, St Petersburg, 1825, p. 52 *sq.*); "Tímúr's Expedition against Tuktamish Khán," Persian and French, by Charmoy, in *Mémoires de l'Acad. Impér. de St Pétersbourg*, 1836, pp. 270–321 and 441–471. (H. E.)

MIROPOLIE, a town of Russia, situated in the government of Kursk, district of Suja, 83 miles south-west of Kursk and 25 miles from the Sumy railway station. It is supposed to have been founded in the 17th century, when it was fortified against the raids of Tartars. The fertility of the soil led to the settlement of large villages close by the fort, and the 10,800 inhabitants of this town are still engaged mostly in agriculture. There is also an extensive manufacture of boots.

MIRROR. It is only since the early part of the 16th century that mirrors have become articles of household furniture and decoration. Previous to that time—from the 12th to the end of the 15th century—pocket mirrors or small hand mirrors carried at the girdle were indispensable adjuncts to ladies' toilets. The pocket mirrors consisted of small circular plaques of polished metal fixed in a shallow circular box, covered with a lid. Mirror cases were chiefly made of ivory, carved with relief representations of love

[1] Mír 'Alíshír not only excelled as poet both in Chaghatái, in which his epopees gained him the foremost rank among the classic writers in that language, and in Persian, but composed an excellent tadhkirah or biography of contemporary Persian poets.

or domestic scenes, hunting, and games, and sometimes illustrations of popular poetry or romance. Gold and silver, enamels, ebony, and other costly materials were likewise used for mirror cases, on which were lavished the highest decorative efforts of art workmanship and costly jewelling. The mirrors worn at the girdle had no cover, but were furnished with a short handle. In 625 Pope Boniface IV. sent Queen Ethelberga of Northumbria a present of a silver mirror; and there is ample evidence that in early Anglo-Saxon times mirrors were well known in England. It is a remarkable fact that on many of the sculptured stones of Scotland, belonging probably to the 7th, 8th, or 9th century, representations of mirrors, mirror cases, and combs occur.

The method of backing glass with thin sheets of metal for mirrors was well known in the Middle Ages at a time when steel and silver mirrors were almost exclusively employed. Vincent de Beauvais, writing about 1250, says that the mirror of glass and lead is the best of all "quia vitrum propter transparentiam melius recipit radios." It is known that small convex mirrors were commonly made in southern Germany before the beginning of the 16th century, and these continued to be in demand under the name of bull's-eyes (*Ochsen-Augen*) till comparatively modern times. They were made by blowing small globes of glass into which while still hot was passed through the pipe a mixture of tin, antimony, and resin or tar. When the globe was entirely coated with the metallic compound and cooled it was cut into convex lenses, which of course formed small but well-defined images. It appears that attention was drawn to this method of making mirrors in Venice as early as 1317, in which year a "Magister de Alemania," who knew how to work glass for mirrors, broke an agreement he had made to instruct three Venetians, leaving in their hands a large quantity of mixed alum and soot for which they could find no use.

It was, however, in Venice that the making of glass mirrors on a commercial scale was first developed; and that enterprising republic enjoyed a rich and much-prized monopoly of the manufacture for about a century and a half. In 1507 two inhabitants of Murano, representing that they possessed the secret of making perfect mirrors of glass, a knowledge hitherto confined to one German glass-house, obtained an exclusive privilege of manufacturing mirrors for a period of twenty years. In 1564 the mirror-makers of Venice, who enjoyed peculiar privileges, formed themselves into a corporation. The products of the Murano glass-houses quickly supplanted the mirrors of polished metal, and a large and lucrative trade in Venetian glass mirrors sprang up. They were made from blown cylinders of glass which were slit, flattened on a stone, carefully polished, the edges frequently bevelled, and the backs "silvered" by an amalgam. The glass was remarkably pure and uniform, the "silvering" bright, and the sheets sometimes of considerable dimensions. In the inventory of his effects made on the death of the great French minister Colbert is enumerated a Venetian mirror 46 by 26 inches, in a silver frame, valued at 8016 livres, while a picture by Raphael is put down at 3000 livres.

The manufacture of glass mirrors, with the aid of Italian workmen, was practised in England by Sir Robert Mansel early in the 17th century, and about 1670 the duke of Buckingham was concerned in a glass-work at Lambeth where flint glass was made for looking-glasses. These old English mirrors, with bevelled edges in the Venetian fashion, are still well known.

The Venetians guarded with the utmost jealousy the secrets of their varied manufactures, and gave most exceptional privileges to those engaged in such industries. By their statutes any glassmaker carrying his art into a foreign state was ordered to return on the pain of imprisonment of his nearest relatives, and should he disobey the command emissaries were delegated to slay the contumacious subject. In face of such a statute Colbert attempted in 1664, through the French ambassador in Venice, to get Venetian artists transported to France to develop the two great industries of mirror-making and point-lace working. The ambassador, the bishop of Béziers, pointed out that to attempt to send the required artists was to court the risk of being thrown into the Adriatic, and he further showed that Venice was selling to France mirrors to the value of 100,000 crowns and lace to three or four times that value. Notwithstanding these circumstances, however, twenty Venetian glass-mirror makers were sent to France in 1665, and the manufacture was begun under the fostering care of Colbert in the Faubourg St Antoine, Paris. But previous to this the art of blowing glass for mirrors had been actually practised at Tour-la-Ville, near Cherbourg, by Richard Lucas, Sieur de Nehou, in 1653; and by the subsequent combination of skill of both establishments French mirrors soon excelled in quality those of Venice. The art received a new impulse in France on the introduction of the making of plate glass, which was discovered in 1691. The St Gobain Glass Company attribute the discovery to Louis Lucas of Nehou, and over the door of the chapel of St Gobain they have placed an inscription in memory of "Louis Lucas qui inventa in 1691 le methode de couler les glaces et installa la manufacture en 1695 dans le château de Saint Gobain."

Manufacture.—The term "silvering," as applied to the formation of a metallic coating on glass for giving it the properties of a mirror, was till quite recently a misnomer, seeing that till about 1840 no silver was used in the process. Now, however, a large proportion of mirrors are made by depositing on the glass a coating of pure silver, and the old amalgamation process is comparatively little used.

The process of amalgamation consists in applying a thin amalgam of tin and mercury to the surface of glass, which is done on a perfectly flat and horizontal slab of stone bedded in a heavy, iron-bound wooden frame, with a gutter running round the outer edge. On the surface of this table, which must be perfectly smooth and level, is spread a sheet of thin tin-foil, somewhat larger than the glass to be operated on, and after all folds and creases have been completely removed, by means of stroking and beating with a covered wooden rubber, the process of "quickening" the foil is commenced. A small quantity of mercury is rubbed lightly and quickly over the whole surface, and the scum of dust, impure tin, and mercury is taken off. Mercury is then poured upon the quickened foil, until there is a body of it sufficient to float the glass to be silvered (about $\frac{1}{4}$ inch deep), and, the edge at one of the sides having been cleared of the scum peculiar to mercury, the glass (scrupulously cleaned simultaneously with the above operations) is slid from that side over the surface of the mercury. Weights are placed over the surface until the greater part of the amalgamated mercury is pressed out, the table is then tilted diagonally, by means of dumb-screws, and all superfluous mercury finds its way to the gutter. The glass is left twenty-four hours under weights; it is then turned over silvered side up, and removed to a drainer with inclining shelves, where by slow degrees, as it dries and hardens, it is brought to a vertical position, which in the case of large sheets may not be arrived at in less than a month. This process yields excellent results, producing a brilliant silver-white metallic lustre which is only subject to alteration by exposure to high temperatures, or by contact with damp surfaces; but the mercurial vapours to which the workmen are exposed give rise to the most distressing and fatal affections.

In 1835 Baron Liebig observed that, on heating aldehyde with an ammoniacal solution of nitrate of silver, in a glass vessel, a brilliant deposit of metallic silver was formed on the surface of the glass. To this observation is due the modern process of silvering glass. In practice the process was introduced about 1840; and it is now carried on, with several modifications, in two distinct ways, called the hot and the cold process respectively. In the former method there is employed a horizontal double-bottomed metallic table, which is heated with steam to from 35° to 40° C. The glass to be silvered is cleaned thoroughly with wet whiting, then washed with distilled water, and prepared for the silver with a sensitizing solution of tin, which is well rinsed off immediately before its removal to the silvering table. The table being raised to the proper temperature, the glass is laid, and the silvering solution at

once poured over it, before the heat of the table has time to dry any part of the surface of the glass. The solution used is prepared as follows:—in half a litre of distilled water 100 grammes of nitrate of silver are dissolved; to this there is added of liquid ammonia (sp. gr. 0·880) 62 grammes; the mixture is filtered, and made up to 8 litres with distilled water, and 7·5 grammes of tartaric acid dissolved in 30 grammes of water are mixed with the solution. About 2·5 litres are poured over the glass for each superficial metre to be silvered. The metal immediately begins to deposit on the glass, which is maintained at about 40° C. (104° F.), and in little more than half an hour a continuous coating of silver is formed. The silvered surface is then cleaned by very cautiously wiping with a very soft chamois rubber, and treated a second time with a solution like the first, but containing a double quantity of tartaric acid. This solution is applied in two portions, and thereafter the glass is once more carefully cleared of all unattached silver and refuse and removed to a side room for backing up.

In silvering by the cold process advantage is taken of the power of inverted sugar to reduce the nitrate of silver. This process has been adopted for the silvering of mirrors for astronomical telescopes, notably for Leverrier's great telescope in the Paris Observatory. For ordinary mirror silvering the following is the process recommended by H. E. Benrath. Two solutions are prepared, the first of which contains the silver salt, and the second the sugar preparation. For the silver solution 800 grammes of nitrate of silver and 1200 grammes of nitrate of ammonium are dissolved in 10 litres of water, and 1·3 kilos of pure caustic soda in 10 litres of water, and of each of these solutions 1 litre is added to 8 litres of water, which is allowed to rest till the sediment forms and then decanted. The second solution—inverted sugar—is prepared by dissolving 150 grammes of loaf sugar with 15 grammes of vinegar in 0·5 litre of water, and boiling the solution for half an hour. After cooling it is made up with water to 4200 cubic centimetres. The silvering is done on horizontal tables in a well-lighted and moderately heated apartment, and the glass is cleaned with scrupulous care. For each square centimetre of glass operated on 15 cubic centimetres of the silver solution above described are measured out, and from 7 to 10 per cent. of the solution of inverted sugar is added, both being quickly stirred together and poured rapidly and evenly over the glass. The reduction immediately begins, and the solution exhibits tints passing through rose, violet, and black, till in about seven minutes it again becomes transparent and the deposit of metal is complete. This first deposit is extremely thin, and allows the transmission of bluish rays. The exhausted solution with floating and unattached dust-like granules of silver is carefully wiped off, the silvered surface washed with distilled water and again treated with the mixed solutions to the extent of half the quantity used in the first application. The finished surface is wiped and washed in the most thorough manner,—for the least trace of caustic soda left would destroy the mirror. The further processes are the same in both methods of silvering.

The deposit of silver on glass is not so adherent and unalterable under the influence of sunlight and sulphurous fumes as the tin-mercury amalgam, and moreover real silvered glass has a slightly yellowish tinge. These defects have been overcome by a process introduced by M. Lenoir, which consists of brushing over the silvered surface with a dilute solution of cyanide of mercury, which instantaneously forming a kind of amalgam renders the deposit at once much whiter and more firmly adherent than before. To protect the thin metallic film from mechanical injury and the chemical action of gases and vapours, it is coated with shellac or copal varnish, over which when dry are applied two coatings of red-lead paint.

Platinum Mirrors.—A cheap process of preparing mirror glass is to some extent prosecuted in France, whereby a thin but very adherent deposit of platinum is formed on the glass. A solution of chloride of platinum with a proportion of litharge and borate of lead dissolved in essential oil of spike is applied with a brush to well-cleaned glass, which is then placed on edge in a muffle furnace, and the platinum is thus burned in, forming an exceedingly thin but brilliant metallic backing having a somewhat grey lustre. It is used only for the lids of cheap boxes, toys, ornamental letters, &c.

Magic Mirrors.—Hand mirrors of metal are still in common use in Oriental countries, and especially in Japan and China they continue to be the prevalent form of looking-glass. In the former country indeed bronze mirrors are articles of the greatest importance in the generally meagre furnishing of houses, and besides possess a religious significance. They have been known and used from the most remote period, mention of them being found in Chinese literature of the 9th century. The (reputed) first made Japanese mirror, preserved at Isé, is an object of the highest veneration in Japan, and an ancient mirror, connected with which is a tradition to the effect that is was given by the sun-goddess at the foundation of the empire, is a principal article of the Japanese regalia. The mirrors of Japan vary in form and size, but in general they consist of thin disks, from 3 to 12 inches in diameter, of speculum metal with handles cast in one piece. The polished face of the mirror is slightly convex in form, so that a reflected image is seen proportionately reduced in size; the back of the disk is occupied with characteristic Japanese ornamentation and inscriptions in bold relief, and its rim is also raised to the back. Much attention has been attracted to these mirrors by a singular physical peculiarity which in a few cases they are found to possess. These are known as magic mirrors from the fact that when a strong beam of light is reflected from their smooth and polished surface, and thrown on a white screen, an image of the raised ornaments and characters on the back of the mirror is formed with more or less distinctness in the disk of light on the screen. This peculiarity has at no time been specially observed by the Japanese, but in China it attracted attention as early as the 11th century, and mirrors possessed of this property sell among the Chinese at ten or even twenty times the price sought for the ordinary non-sensitive examples. The true explanation of the magic mirror was first suggested by the French physicist Person, who observed that the reflecting surface of the mirrors was not uniformly convex, the portions opposite relief surfaces being plane. Therefore, as he says, "the rays reflected from the convex portion diverge and give but a feebly illuminated image, while, on the contrary, the rays reflected from the plane portions of the mirror preserve their parallelism, and appear on the screen as an image by reason of their contrast with the feebler illumination of the rest of the disk." That such differences of plane in the mirror surface arise is an accidental circumstance due to the manner in which it is prepared, a process explained by Professors Ayrton and Perry, by whom ample details of the history, process of manufacture, and composition of Oriental mirrors have been published. A preliminary operation in polishing the surface consists of scoring the cast disk in every direction with a sharp tool. The thicker portions with relief ornament offer more resistance to the pressure of the tool than the thin flat portions, which tend to yield and form at first a concave surface, but this by the reaction of its elasticity rises afterwards and forms a slightly convex surface while the more rigid thick portions are comparatively little affected. This irregularity of surface is inconspicuous in ordinary light, and does not visibly distort images; but when the mirror reflects a bright light on a screen the unequal radiation renders the minute differences of surface obvious. The ingenious theory of Person has been established by experiments communicated by M. Govi to the academy of Turin in 1864-65, and more recently by investigations of MM. Bertin and Dubosq. See *Annales de Chimie et de Physique* (5th ser., vol. xx.). (J. PA.)

Ancient Mirrors.

The mirror of classical antiquity (*κάτοπτρον*, speculum) was a thin disk of bronze slightly convex on one side and polished, usually provided with a handle, sometimes mounted on a stand in the form of a female figure (see COSTUME, vol. vi. p. 453, fig. 1), sometimes fixed inside a circular bronze case. The common size is that of an ordinary hand mirror. Examples large enough to take in the whole figure appear to have been rare. Mirrors of glass are mentioned, and though none of them have been found their existence need not be questioned altogether, since the process of silvering occasionally employed on bronze mirrors suggests that an analogous process may have been applied to glass. But the very large number of mirrors still existing from antiquity shows that bronze was the regular material employed. The alloy known as speculum, producing a very hard metal with great reflecting power, is comparatively seldom met with. Silver mirrors are mentioned, but none have as yet been found.

The principal feature of ancient mirrors, especially those of Etruria, is the design incised on the back (see ETRURIA, vol. viii. p. 643). While twelve incised specimens are all that are as yet known from Greece, the number found in Etruria must be nearly a thousand. As a rule the subjects incised are taken from Greek mythology and legend, the names of the persons represented being frequently added in Etruscan letters and orthography. In most cases the style of drawing, the types of the figures, and the manner of composing the groups are true to the characteristics of Greek art. Some may have been imported from Greece; but the greater number appear to have been more or less faithfully imitated from such designs as occurred on the almost innumerable printed Greek vases which the Etruscans obtained from Greece. Even where distinctly Etruscan figures are introduced, such as the heroes Ælius and Cælius Vibenna on a mirror in the British Museum, Greek models are followed. The characteristics of Greek art here referred to date from a little before 400 B.C., and last for some time after. In this period would fall the majority of the Etruscan mirrors, and to this period also belong the Greek incised mirrors, among which may be mentioned for their beauty one representing Leucas and Corinthus, inscribed with their names (engraved, *Monuments Grecs*, 1873, pl. 3, published by the Association pour l'encouragement des Études Grecques), and another in the British Museum (*Gazette Arch.*, ii. pl. 27), on the back of which is a figure of Eros which has been silvered over. With this last-mentioned mirror was found the bronze case used to contain it,

on the back of which is a group of Aphrodite and Eros in repoussée. It was found in Crete. But most of the Greek mirrors and mirror-cases having artistic designs are from Corinth. One bears the name of the artist, Ἀπολλᾶς ἐποίει (engraved, *Arch. Zeitung*, 1862, pl. 166, fig. 1).

Archaic art (about 500 B.C.) is represented by a mirror in the British Museum from Sunium in Attica. The mirror itself is quite plain, but the stand is composed of a draped female figure, above whose head float two cupids. From Etruria there is a comparatively small number with archaic incised designs. It may be concluded that the luxury of mirrors enriched with incised designs was not freely indulged before 400 B.C. in Etruria and never to any extent in Greece. A special centre of incised mirrors was the Latian town of Præneste (Palestrina), and it is of interest in regard to some of the mirrors found there that they have inscriptions in early Latin. Artistically they have a purely Greek character. Plain mirrors are found wherever Greek and Roman civilization spread, and it may be seen from a specimen found in Cornwall, now in the British Museum, that the Celtic population of England had adopted the form and substance of the mirror from their conquerors. This specimen is enriched with a Celtic pattern incised. The shape of the handle testifies to native originality. Mirrors were used in Greece, perhaps rarely, for divination, as appears, for example, from Pausanias (vii. 21, 5), the method being to let the mirror down into a well by means of a string till it reached close to the surface of the water. When it was pulled up after a little it was expected to show the face of the sick person on whose behalf the ceremony was performed. This was at Patras.

The principal publications on ancient mirrors are Gerhard, *Etruskische Spiegel*, Berlin, 1843-67, 4 vols., containing 430 plates; for the Greek mirrors, Mylonas, Ἑλληνικὰ κάτοπτρα, Athens, 1876, and Dumont, *Bullet. de Corresp. Hellén.*, 1877, p. 108; see also Friederichs, *Kleinere Kunst und Industrie im Alterthum*, Düsseldorf, 1871, p. 18 *sq.*; and Marquardt and Mommsen, *Handbuch der römischen Alterthümer*, vii. pt. 2, p. 670. (A. S. M.)

MÍRZÁPUR, a district in the North-Western Provinces of India, lying between 23° 51′ 30″ and 25° 31′ N. lat., and between 82° 9′ 15″ and 83° 0′ 36″ E. long., is bounded on the N. by Jaunpur and Benares, on the E. by Shahábád and Lohárdagá, on the S. by Sargújá state, and on the W. by Allahábád and Rewah state, and has an area of 5217 square miles. It is crossed from east to west by the Vindhya and Káimur ranges. A central jungly plateau connects these, and separates the valley of the Ganges from that of the Son.

The population in 1872 was 1,015,203 (males, 520,496; females, 494,707), of whom 949,644 were Hindus, 64,809 Mohammedans, and 750 Christians. The non-Asiatic population numbered 623. Only three towns had a population exceeding 5000:—Mírzápur, 67,274; Chanár, 10,154; and Ahraura, 9091. Out of a Government-assessed area of 3048 square miles, 1313 are cultivated, 497 cultivable waste, and 1238 uncultivable. The part of Mírzápur which lies north of the Vindhyás is very highly cultivated and thickly peopled, but the rest of the district consists largely of ravines and forests, with a very sparse population. Local manufactures comprise carpets of a superior description, brass ware, and shellac. The East Indian Railway traverses the district, along the right bank of the Ganges, for a distance of 32 miles. The climate is slightly warmer and damper than that of districts farther north and east. The mean annual rainfall is 42·7 inches.

MÍRZÁPUR, chief town and administrative headquarters of the above district, is situated on the south bank of the Ganges, 56 miles below Allahábád (25° 9′ 43″ N. lat., 82° 38′ 10″ E. long.). The population in 1872 was 67,274, of whom 55,917 were Hindus and 11,053 Mohammedans. Up to quite recent years Mírzápur was the largest mart in upper India for grain and cotton; but of late its commercial importance has rapidly decreased, owing to the establishment of through railway communication with Bombay *via* Jabalpur, and the rise of Cawnpore to the position of a mercantile centre. The river front, lined with stone *gháts* or flights of stairs, and exhibiting numerous mosques, Hindu temples, and dwelling-houses of the wealthier merchants, with highly decorated façades and richly carved balconies and door-frames, is handsome; but the interior of the town is mainly composed of mud huts. The manufacture of shellac gives employment to about four thousand persons; brass ware and carpets are also made. The imports consist of grain, sugar, cloth, metals, fruit, spices, tobacco, lac, salt, and cotton; the same articles, with manufactured lac-dye, shellac, and *ghí*, are exported.

MISDEMEANOUR. "The word misdemeanour," says Russell (*On Crimes*, vol. i. chap. iv.), "is applied to all those crimes and offences for which the law has not provided a particular name." Stephen, in his *Digest of the Criminal Law*, adopts the following mode of distinguishing between misdemeanour and other crimes. "Every crime is either treason, felony, or misdemeanour. Every crime which amounts to treason or felony is so denominated in the definitions of crimes hereinafter contained. All crimes not so denominated are misdemeanours." It is customary to speak of misdemeanour as implying a less degree of crime than felony (see FELONY). "Misdemeanours," observes Russell in the passage already cited, "have been sometimes termed *misprisions*; indeed the word misprision, in its larger sense, is used to signify every considerable misdemeanour which has not a certain name given to it in the law, and it is said that a misprision is contained in every felony whatsoever, so that the offender may be prosecuted for misprision at the option of the crown." Misprision, in a more restricted sense (or negative misprision), is the concealment of an offence. Positive misprisions are contempts or misdemeanours of a public character, *e.g.*, mal-administration of high officials, contempt of the sovereign or magistrates, &c. The rule as to punishment, when no express provision has been made by law, is that "every person convicted of a misdemeanour is liable to fine and imprisonment without hard labour (both or either), and to be put under recognizances to keep the peace and be of good behaviour at the discretion of the court" (Stephen's *Digest*, art. 22). By 28 & 29 Vict. c. 67 prisoners convicted of misdemeanour and sentenced to hard labour shall be divided into two divisions, one of which shall be called the first division, and when a person convicted of misdemeanour is sentenced to imprisonment without hard labour the court may order him to be treated as a first-class misdemeanant, who shall not be deemed a "criminal prisoner" within the meaning of that Act. The Prison Act, 1877 (§§ 40, 41), requires prisoners convicted of sedition or seditious libel, or attached for contempt of court, to be treated as misdemeanants of the first class.

In New York and some other States of the American Union the legislature has defined felony as any crime which is or may be punishable with death or imprisonment in a State prison, all other crimes being misdemeanours.

MISHNAH. The *Mishnah*, in the most familiar application of the name, is the great collection of legal decisions by the ancient rabbis which forms in each Talmud the text on which the *Gemara* rests, and so is the fundamental document of the oral law of the Jews. The question What is Mishnah? was asked, however, as early as the latter part of the 1st or the early part of the 2d century, though in a somewhat different sense and for a somewhat different purpose.[1] It will be answered in the course of this article in all its bearings.

1. *Name.*—Rabbinic tradition has fixed the pointing *Mishnah* (מִשְׁנָה) by giving its *status constructus* as *Mishnath*. Although the word *Mishnah* is not found in the Bible, it is no doubt a classical Hebrew term, signifying something closely akin to *Mishneh* (which term occurs more than once there), as may be seen on comparing *Mikvah* with *Mikveh*, *Miknah* with *Mikneh*, *Ma'alah* with *Ma'aleh*, and *Mar'ah* with *Mar'eh*, each two of which are, however they may vary in practical application, unquestionably synonymous terms. The practical significations of *Mishnah* are seven in number:—(1) repetition, *i.e.*, tradition:[2] as such it is the equivalent of the

[1] See T. B., *Kiddushin*, 49*a*.

[2] The root *Shanoh* (שָׁנֹה), from which *Mishnah* is immediately derived, is not merely, as is often thought, to *learn*, to *teach*, but to *repeat*; and it is in reality this last meaning which underlies the two former.

δευτερώσεις of Epiphanius,[1] the *traditiones et δευτερώσεις* of Jerome,[2] the δευτέρωσις of Justinian,[3] and the שניה לתורה ("the second to the law") of the *Arukh*[4]; (2) recitation from memory, in contradistinction to reading from a book;[5] (3) study: as such it is the equivalent of *Midrash* in the former part of its third signification; (4) instruction: as such it is the equivalent of *Midrash* in the latter part of its third signification;[6] (5) system, style, view, line of study and instruction: as such it is identical with the Talmudical *Shittah*;[7] (6) a paragraph of the *Mishnah*: it is invariably employed in this sense in the Babylonian Talmud, and is identical with the word *Halakhah*, used for the same purpose, in the Palestinian Talmud; and (7) the collection of the decisions of the whole "oral law," *i.e.*, the *Mishnah* in the concrete sense. The word *Mishnah* has three different plurals:—(1) the traditional *Mishnayoth* for signification (7), formed on the analogy of *Miḳvaoth* (not, as some think, on that of *Miḳraoth* or *Midrashoth*); (2) the correct, though questioned, *Mishniyyoth* for signification (6), formed on the analogy of *Parshiyyoth* from *Parashah* (or *Parshah*), not to speak of that of *Ma'asiyyoth* from *Ma'aseh*; (3), the somewhat inelegant, but correct, *Mishnoth*,[8] which also serves for signification (6). Significations (1), (2), (3), (4), and (5) have, however inconsistent it may appear when one takes into consideration their respective equivalents, no plural whatever. So much for the Hebrew *Mishnah*. The Aramaic *Mathnitho* will be spoken of later.

2. *Contents and Nature.*—The *Mishnah* consists chiefly of *Halakhah*;[9] there is, comparatively speaking, little *Agadah*[10] to be found in it. It is not, however, as many think, either a commentary on the Halakhic portions of the Pentateuch, or on the ordinances of the *Sopherim*, or on both together. It rather presupposes the knowledge of, and respect for, both the Mosaic and the Sopheric laws, and it only discusses, and finally decides on, the best mode and manner of executing these. The discussions and eventual decisions to be found in the *Mishnah* owe their existence principally to deep meditation on these two kinds of laws, notably on the former, by the rabbis of various ages, but chiefly by those who lived fifty years before and one hundred and fifty years after the rise of Christianity, the names of whom it faithfully gives, along with their respective discussions and decisions. There are but few cases to be found in the *Mishnah* which would critically come under the denomination of an *Halakhah le-Mosheh mis-Sinai, i.e.*, an explanation (of a law) as directly given by God to Moses, and in uninterrupted succession received from him by the rabbis. Several cases given under this name in the *Mishnah* are not *bona fide* cases;[11] for the test of such an *Halakhah* is that it must never have been contested by any one.[12]

3. *Method.*—A *Mishnah*, if genuine, never begins with a passage of the Pentateuch, and even comparatively seldom brings direct proof from or gives reference to it. When there is any exception to this rule it will be found, on close examination, either that such a paragraph belongs to a very early age (that of the *Sopherim*), or that it is to be found in another work of the "oral law," and is simply copied in the *Mishnah*, or, what is more likely, that, if independent, it belongs to a very late age, or, finally, that the proof or the reference thus given is only a later addition. One example of the true method of the *Mishnah* will, perhaps, better illustrate the foregoing statement than a sheet full of theorizing on the subject; and this one example will the more surely suffice because of its mixed (Mosaic and Sopheric) character. It is the very first paragraph of the whole *Mishnah*, and runs thus: "From what time (of the day) does (may, should) one read the *Shema'* ('the taking upon oneself the yoke of the heavenly kingdom') in the evening?" The *Mishnah* does not begin: One is in duty bound to read the *Shema'* in the evening, because it is written (Deut. vi. 7), "And when thou liest down." For, in the first place, the law to read the *Shema'* evening and morning is not unquestionably Mosaic, as the words, "And thou shalt talk of them, &c.," do not refer to this passage of the law particularly, but rather to the words of the Pentateuch in general;[13] and, secondly, it is needless to say that one is in duty bound to recite the *Shema'* twice a day, since every Jew readily acknowledges this duty and executes it, although it is not Mosaic. This duty of reading the *Shema'*, the grounds on which this duty rests, and how it is best fulfilled, are fully and ably discussed, developed, and finally settled in that part of the Talmud called *Gemara*,[14]—the business of which it is to discuss the words of the *Mishnah* and to show the sources of the tradition, and eventually the passage in the Pentateuch (if on such the case rest) from which the respective disputants had derived their views, &c.

4. *Purpose.*—Although it is a book containing Halakhic decisions, the *Mishnah* was never intended, as many think, to enable the reader thereof to decide from it immediately. This mistake is old[15] and widely spread,—but a mistake nevertheless. The purpose of the *Mishnah* was and is simply to exhibit the development of the "oral law" and the view taken of this development by the rabbis of various times. For this reason one finds side by side with the opinions of the majority those also of the minority, which latter are very carefully given. But why, since these opinions of the minority can have no decisional effect? The *Mishnah* itself (*'Eduyyoth*,[16] i. 5)

[1] *Hæres.*, xv. (κατὰ γραμματέων), *in fine.* Epiphanius was a native of Palestine, even if he was not, as some think, of Jewish parentage. As a Palestinian writer on Jewish and semi-Jewish matters he must have had a more than superficial knowledge of the Jewish traditions (the *Mishnah*, &c.). And indeed, to judge from the account he gives of the various Jewish traditions (although the text of this account is extremely corrupt in every way), he was pretty well informed. For he tells us that the Jews have four kinds of traditions:—such as are ascribed to Moses (by which he no doubt means the *Halakhah le-Mosheh mis-Sinai*); such as are ascribed to the sons of Asmonæus (by which he means the *Teḳanoth*, &c., of the *Beth Dino shel Ḥashmonai*; see T. B., *'Abodah Zarah*, 36*b*); such as are ascribed to R. 'Aḳibah (the great teacher and martyr); and such as are ascribed to R. Andan, &c. (Rabbi Yehudah Hannasi).

[2] *In Isaiam*, cap. viii. 11–15.

[3] *Nov.* cxlvi. (Περὶ Ἑβραίων) κεφ. ά, *in medio.*

[4] Article משנה (first definition).

[5] Contrast *Shanoh* (שָׁנֹה) with *Ḳaro* (קָרֹא).

[6] See article MIDRASH, p. 285.

[7] See Schiller-Szinessy, *Catalogue of Hebrew MSS. in the Cambridge University Library*, ii. p. 94.

[8] See MS. Add. 464 (University Library, Cambridge), leaf 283*b*.

[9] This word, derived from the root *Halokh* (הָלֹךְ), to go, is synonymous with *Minhag* (custom, practice) and *Mishpat* (rule), &c.

[10] For the meaning of this term and the Agadic parts which are to be found in the *Mishnah*, see MIDRASH.

[11] See R. Asher b. Yeḥiel (Harosh), *Hilekhoth Miḳvaoth* (coming close after this Rabbi's commentary on *Niddah*, in the printed editions of the Bab. Talmud), i. 1.

[12] There are, however, at least sixteen such *bona fide* cases to be found in the works of the "oral law."

[13] See T. B., *Berakhoth*, on Deut. xi. 19.

[14] *Gemara*, or *Gemoro*, signifies concretely discussion on and final settlement of the contents of the *Mishnah*, from *gemar* (גְּמַר), to study deeply, to come to a final result; which last signification is, to some extent, to be found also in the Hebrew root *gamor* (גָּמֹר). Compare T. B., *Bobo Metsi'o*, 33*a*, and Rashi, *in loco.*

[15] See T. B., *Sotah*, 22*a*.

[16] The word עדיות is variously pointed:—*'Aduyoth*, *'Ediyoth*, and, as in the text, *'Eduyyoth*, which last, if the name come from עדות, because of the testimony of the witnesses on which this *Massekheth* chiefly rests, would be the only correct one. But it ought to be remarked that the Babylonian teachers must have spelled it *'Idiyyoth* (best things), since its equivalent is given by them as *Beḥirto* (or *Beḥirotho*). See T. B., *Berakhoth*, 27*a* and elsewhere.

answers this question: it is that the teacher or the judge of later ages may be thus enabled, if he have good grounds for taking a view different from that of the majority as given hundreds of years before, to reverse the old decision, by forming, on the strength of the example before him, with others who agree with him (or without them, if only one vote was wanted to reverse the majority) a fresh majority. Thus the Jewish "oral law" can never become ossified like the laws of the Medes and Persians.

5. *Language.*—The *Mishnah* is, on the whole, written in almost pure Hebrew; and even the originally non-Hebrew words (Aramaic, Greek, Latin, &c.) are so skilfully Hebraized that they are a most creditable testimony to the linguistic powers both of many of the disputants mentioned in it, whose very words are in most cases given, and of the editor[1] or editors who revised them.

6. *Age and Authorship.*—R. Yehudah Hannasi (the Prince), the reputed author (in reality only the principal and best among the editors) of the *Mishnah*, was born before the year 140 of the Christian era. His name was in full Yehudah b. Shimeʿon b. Gamliel b. Shimeʿon b. Gamliel[2] b. Shimeʿon b. Hillel. On account of his holy living he was surnamed Rabbenu Hakkadosh, and on account of his great learning and authority he was called simply "Rabbi" ("My Teacher" *par excellence*). Rabbi and his time, however, are no *terminus a quo* for the composition of the *Mishnah*. For, not to speak of many isolated *Mishniyyoth* which can be brought home to R. Meir, to R. ʿAkibah, to Hillel,[3] to Yose b. Yoʿezer,[4] and to others, even to the earlier *Sopherim*,[5] we find that R. Yose b. Ḥalaphta of the 1st century already quotes the beginning and ending of a whole Mishnic treatise (*Kelim*[6]), and that in the same century (or very early in the 2d) another treatise consisting of early testimonies (*ʿEduyyoth*[7]) was put into order. Moreover, although the phrases *Mishnath R. Eliʿezer b. Yaʿakob*[8] and *Mishnath R. ʿAkibah*[9] do simply signify the systems, styles, and views of these two eminent teachers, there can be little doubt that they and others besides them, presided over colleges in which the whole Halakhic matter was systematically treated and regularly gone through. Nor are Rabbi and his time for the composition of the *Mishnah* a *terminus ad quem*, for the *Mishnah* was not brought to a close till a very long time afterwards. Not only did R. Ḥiyya Rabbah, R. Hoshaʿyah Rabbah, and Shimeʿon bar Kappara redact *Mishnayoth*,[10] but in the *Mishnah* before us notices are actually found which reach to the end of the 3d century, if not even later. The statement that Rabbi was the first to write down the *Mishnah* is untrue, because the thing is impossible. For the two Talmuds, of which that of Babylonia was not finished before the 6th century (if then), know, certainly, nothing of the writing down of the *Mishnah*. On the contrary, their language throughout presupposes the *Mishnah* in their time to have been what its name indicates, a repetition, *i.e.*, a thing acquired by continual recitation, because, like the other works of the "oral law" (*Torah shebbeʿal peh*), it was to be, and was, handed down orally.[11] As for the difficulty of keeping in memory such a stupendous and vast work as the *Mishnah*, it is sometimes forgotten in this controversy that memory was aided by a great variety of mnemotechnic means, such as numbers and names of teachers, and by the existence of other works of the "oral law," which, although they also were not written down, could be easily kept in memory because they rested on letters, words, and verses of the written Pentateuch. Anyhow, there is ample evidence, both negative and positive, that the *Mishnah* as we now have it was not committed to writing in the times of Rabbi or for long afterwards. But it certainly does not follow that no merit is due to Rabbi in connexion with the *Mishnah*. His merit in connexion with it is great in every way. For (1) Rabbi was himself a link in the chain of tradition, since he had "received" from his own father and so on up to his ancestor Hillel and even higher; (2) he gave in the *Mishnah* his own decisions, in most cases in accordance with those of the famous R. Meir, which are thus in a great part secured to us; (3) in giving his own decisions he preserved to us also a good many decisions of the teachers of the 2d century; (4) in collecting all these decisions he anxiously ascertained the genuine formulas of the older *Mishniyyoth*;[12] (5) he did not merely reproduce the formulas which he esteemed the best, but discussed them anew in his own college, which was composed of men of the highest eminence, as is well known; (6) although he gave on the whole the very language of the teachers who preceded him, he gauged it, guarding it against the barbarisms which are so plentiful in the other works of the "oral law"; and (7) he scattered the *Mishnah* broadcast (though only by word of mouth) over all Palestine and Babylonia by means of the disciples who flocked to him from all parts of those countries. If the *Mishnah*, as it now exists, is not entirely his, it certainly belongs to him in a great measure and in more than one sense.

7. *Value and Appreciation.*—Whatever can be said in favour of the *Agadah* applies with equal if not greater force to the *Mishnah*, as the latter is a canonical and therefore more reliable work of the "oral law." The *Mishnah* is one of the richest mines of archæology which the world possesses. But it waits yet for the master touch to break the spell which holds it bound. Great, however, as the value of the *Mishnah* is, its popularity has never been steady, but has been continually fluctuating, and that for various reasons. Even Rabbi in his time had to appeal for due attention to it. Whilst it was neglected in troublous times by the masses, who ran after the *Agadah*,[13] which, besides being consoling, needed no particular study, it was, in prosperous times, neglected by the rabbis themselves through the study of the Bible and the Talmud.[14] And much more was this

[1] The Hebrew spoken in the house of the principal editor of the *Mishnah* was so correct that rabbis actually learnt the meaning of uncommon words of the Bible from the handmaidens of this house. See T. B., *Rosh Hasshanah*, 26*b*. As for Rabbi himself, he was not merely a fine Hebrew scholar, but a fine Greek scholar also. He was also a purist; for in T. B., *Sotah*, 49*b*, he is reported to have exclaimed, "Why should any one speak in Palestine 'Sursi'? Let him speak either Hebrew or Greek!" In using the word "Sursi" for "Surith" (Syriac), he no doubt makes a punning allusion to the mixed (cut-up) character of the language, corrupted from Hebrew, Chaldee, Persian, Greek, and Latin.

[2] This was the teacher of St Paul.

[3] In addition to such well-known Agadic *Mishniyyoth* as those which are distinctly ascribed in *Aboth* to Hillel, see *Mishnah Kiddushin*, iv. 1; and contrast it with the language and style of the *Mishnah* in general, and that of *Massekhto Kiddushin* in particular.

[4] *Mishnah ʿEduyyoth*, viii. 4.

[5] See *Mishnah Maʿaser Sheni*, v. 7; *Sotah*, v. 1, 2; *Negaʿim*, xii. 5, 6, 7, &c.; though it cannot be said that these passages preserve the teaching of the *Sopherim* in their original purity.

[6] See *Mishnah Kelim*, *in fine*.

[7] See T. B., *Berakhoth*, 28*a*: "It is handed down orally (תנא) that *Eduyyoth* was on that day (when R. Elʿazar b. ʿAzaryah was installed as president) gone through," *i.e.*, redacted.

[8] T. B., *Yebamoth*, 49*b*.

[9] *Mishnah Synhedrin*, iii. 4.

[10] See *Koheleth Rabbah* on ii. 8 *in medio*.

[11] See particularly T. B., *Bobo Metsiʿo*, 33*a* and *b*; and compare also Rashi, *in loco*.

[12] See T. Y., *Maʿaser Sheni*, v. 1; and compare the preceding note.

[13] See MIDRASH, p. 285, note 14.

[14] R. Yohanan said, This *Mishnah* (*Boraitho*), that no study can excel that of *Gemara*, was taught in the time of (and by) Rabbi himself. Then the people went after *Gemara* and neglected the study of the *Mishnah*. Whereupon he again bade them ever run more after *Mishnah* than after *Gemara*. T. B., *Bobo Metsiʿo*, 33*b*, and Rashi, *in loco*.

the case when the Talmud had developed from a mere studious activity to two concrete works of large size.

8. *The Ultimate Writing Down of the Mishnah.*—The troubles of the unhappy Jews had multiplied everywhere. The masses, as already stated, preferred, in consequence of these troubles, the *Agadah*. But the number of the learned also diminished through these troubles day by day; and the comparatively few that remained preferred more and more the Talmud (in Palestine the Palestinian and in Babylonia the Babylonian), which was a better field for the exercise of their ingenuity. The fate of the *Mishnah* would have been sealed had it not been ultimately written down. But the writing down of *Halakhah en masse* had been prohibited in early times. Two considerations, however, ultimately removed all scruples. (1) It was a time to do something for God, even if by such doings His law was apparently destroyed.[1] Let one (and a minor) law be disregarded, so that many (and higher) laws be preserved. The *Halakhoth* of the *Mishnah* were numerous and the students few; the power of tyranny increased and that of the memory decreased by reason of the persecution. (2) The language of the *Mishnah*, although pure, and indeed purer than the language of several books of the Bible, was so concise and terse that it could not be understood without a commentary; and, therefore, even after being written down, it would virtually retain its oral character.

9. *Recensions.*—The *Mishnah* has three principal recensions:—(1) the *Mishnah* as presented in the work standing by itself; (2) that on which the Palestinian Talmud rests; and (3) that of the Babylonian Talmud. The first-named and the last-named *Mishnayoth* have always been known as complete; the second, however, was supposed for several hundred years to be imperfect, lacking four *Peraḳim* in *Shabbath*, two entire *Massekhtoth* in the *Seder Neziḳin*, the whole of the *Seder Ḳodoshim*, and by far the greater part of the *Seder Tohoroth*.[2] But since 1869 this recension also has been known to have been always complete; and it is to be found in its entirety in a MS. purchased in that year for the University Library of Cambridge (Add. 470. 1). Besides these three there are many minor recensions, touching, however, only isolated readings. These last are to be attributed chiefly to copyists. The origin of the difference between the principal recensions is to be sought in the following two facts:—(1) Rabbi had himself gone twice through the *Mishnah* and had himself considerably altered the wording of the text;[3] and (2) his successors in early and late times had wilfully altered and corrected the original text.

10. *Divisions and Detailed Contents of the Mishnah.*—The *Mishnah* in all recensions is divided into six *Sedarim* (orders), each of which contains a number of *Massekhtoth*[4] (treatises), which stand in connexion with one another. These are subdivided into *Peraḳim* (chapters), and these again into *Halakhoth* or *Mishniyyoth* (paragraphs called *Mishnoth*).[5] The number of the *Sedarim* is six, that of the *Massekhtoth* sixty,[6] and that of the *Peraḳim* 523, or, with a fourth *Pereḳ* to *Bikkurim*, 524.[7] The following is a scheme of the whole *Mishnah*.[8]

I. Zera'im (on Agriculture, preceded by the Treatise on Thanksgivings[9]). (1) *Berakhoth* (blessings), in nine chapters; (2) *Peah* (Lev. xix. 9, &c.), in eight chapters; (3) *Demai* (fruit, grain, &c., doubtful if tithed), in seven chapters; (4) *Kil'ayim* (mixtures of plants, animals, and garments respectively), in nine chapters; (5) *Shebi'ith* (year of release), in ten chapters; (6) *Terumoth* (gifts to the priests), in eleven chapters; (7) *Ma'aser Sheni*[10] (Deut. xiv. 22–27), in five chapters; (8) *Ma'aser Rishon*, otherwise *Ma'aseroth* (Levitical tithes), in five chapters; (9) *Hallah* (Num. xv. 19–21), in four chapters; (10) *'Orlah* (Lev. xix. 23), in three chapters; and (11) *Bikkurim* (Deut. xxvi. 1–10), in three (commonly four) chapters.

II. Mo'ed (on Festival Times). (1) *Shabbath* (Sabbath), in twenty-four chapters; (2) *'Erubin* (mixtures, *i.e.*, ideal union of divided spaces), in ten chapters; (3) *Pesaḥ* (commonly *Pesaḥim*, *i.e.*, Passover), in ten chapters; (4) *Kippurim* (commonly *Yoma*, *i.e.*, "the day" [of atonement]), in eight chapters; (5) *Sheḳalim* (Exod. xxx. 12–15), in eight chapters; (6) *Sukkah* (Lev. xxiii. 34–43), in five chapters; (7) *Betsah* ("an egg," so called from the beginning of the treatise; also *Yom Tob*, *i.e.*, on work prohibited, or permitted, on festivals), in five chapters; (8) *Rosh Hasshanah* (on the various kinds of new year, as religious or civil, the king's accession and coronation, &c.), in four chapters; (9) *Ta'aniyyoth* (fast-days), in four chapters; (10) *Megillah* (reading of the book of Esther, other readings, &c.), in four chapters; (11) *Hagigah* (festival-offerings), in three chapters; (12) *Mashḳin* (so called from the beginning of the treatise, but commonly *Mo'ed Katan*, on work prohibited, or permitted, on the middle holidays of Passover and Tabernacles), in three chapters.

III. Nashim (Women). (1) *Nashim* (so called from the first distinctive word of the treatise, but commonly *Yebamoth*, on sisters-in-law, the levirate, &c.), in sixteen chapters; (2) *Kethuboth* (marriage-pacts, settlements, &c.), in thirteen chapters; (3) *Nedarim* (vows), in eleven chapters; (4) *Nazir* (Num. vi. 2–21), in nine chapters; (5) *Gittin* (bills of divorcement and other bills), in nine chapters; (6) *Kiddushin* (betrothal and marriage), in four chapters; (7) *Sota* (mostly *Sotah*, Num. v. 12–31), in nine chapters.

IV. Neziḳim, commonly *Neziḳin* (Damages, &c.; see Exod. xxi., xxii., &c.). (1) *Neziḳin* (commonly *Bobo Ḳammo*, the Former Gate, in ten chapters; *Bobo Metsi'o*, the Middle Gate, in ten chapters; and *Bobo Bathro*, the Last Gate, in ten chapters[11]), in thirty chapters; (2) *Synhedrin* (courts of justice, &c.), in eleven chapters; (3) *Makkoth* ("forty stripes save one," &c.), in three chapters; (4) *Shebu'oth* (oaths, &c.), in eight chapters; (5) *'Eduyyoth* (testimonies) or *'Idiyyoth* (chiefest or best things[12]), in eight chapters; (6) *'Abodah Zarah* (idolatry), in five chapters; (7) *Aboth* (see Midrash, p. 286), in five chapters; (8) *Horayoth* (judicial errors, teachings, and decisions), in three chapters.

V. Kodoshim (Holy Things). (1) *Zebaḥim*[13] (sacrifices), in fourteen chapters; (2) *Menaḥoth* (meat-offerings), in thirteen chapters; (3) *Sheḥitath Ḥullin* (slaying animals for common food; commonly *Ḥullin*, or common food), in twelve chapters; (4) *Bekhoroth* (the first-born of beast and man), in nine chapters; (5) *'Arakhim*, commonly *Erachin* (on valuations; see Lev. xxvii. 2–33), in nine chapters; (6) *Temurah* (Lev. ix. 10, 33), in seven chapters; (7) *Karethoth*, not *Kerithoth* (sins the punishment of which is excision), in six chapters; (8) *Me'ilah* (Num. v. 6, 7), in six chapters; (9) *Middoth* (description of the temple and its measurements; see Midrash, p. 286), in five chapters; (10) *Tamid* (perpetual or daily sacrifice), in six (commonly arranged in seven) chapters; (11) *Kinnim* (sacrifices of birds), in three chapters.

VI. Tohoroth (Purifications). (1) *Kelim* (impurities of vessels), in thirty chapters; (2) *Oholoth* (Num. xix. 14–16, &c.), in eighteen chapters; (3) *Nega'im* (plague of leprosy in man, house, and garment), in fourteen chapters; (4) *Parah* (Num. xix. 1–19), in twelve chapters; (5) *Tohoroth* (euphemism for impurities), in ten chapters; (6) *Miḳvaoth* (religious baths), in ten chapters; (7) *Niddah* (Lev. xv. 19–33), in ten chapters; (8) *Makhshirim* (liquids

[1] This is a somewhat inexact application of Ps. cxix. 126, but it has been more than once acted upon both in ancient and modern times by the Jews. Compare the explanation given in T. B., *Berakhoth*, 63*a*, and *Menaḥoth*, 99*a*.

[2] *Niddah* is the only *Massekheth* of this *Seder* of which three entire *Peraḳim* are to be found in the printed editions. Compare Schiller-Szinessy, *Occasional Notices*, &c., i. (Cambridge, 1878, 8vo) p. 8.

[3] See T. B., *Bobo Metsi'o*, 44*a*, and elsewhere.

[4] Whether the word *Massekheth* comes from *Masokh* (מָסַךְ, to pour into, to mix, &c.), or from *Nasokh* (נָסַךְ, to pour, to mix, to weave, &c.), it signifies in either case here a mould, a form, a frame. *Massekheth* has three several plurals:—(1) the common *Massekhtoth* (not *Massikhtoth*); (2) the less common *Massekhoth* (see MS. Add. 470. 1, belonging to the University Library of Cambridge, leaf 69*a* and elsewhere); and (3) *Massekhtiyyoth* (מסכתיות), see *Midrash Rabbah* on Canticles vi. 8, 9. The Aramaic *Massekhto* (not *Massikhto*) has in the plural *Massekhotho*, the use of which is, however, very uncommon.

[5] Compare above, p. 503.

[6] Compare *Midrash Rabbah* on Canticles vi. 8, 9.

[7] Others include, instead of a fourth *Pereḳ of Bikkurim*, the *Pereḳ Rabbi Meir*, *i.e.*, the treatise "On the Acquisition of the Law." The original *Mishnah*, however, had neither of these two *Peraḳim*.

[8] *In this scheme the Cambridge MS. of the Mishnah is taken as* the groundwork, while the variations in title, &c., are given from the common texts.

[9] Compare St Paul's words, Eph. v. 20, εὐχαριστοῦντες πάντοτε ὑπὲρ πάντων.

[10] On the apparent anomaly of *Ma'aser Sheni* preceding *Ma'aser Rishon*, see Schiller-Szinessy's *Catalogue of Hebrew MSS. in the Cambridge University Library*, vol. ii. p. 1, note 4.

[11] In the Cambridge MS. Add. 470. 1, *Massekhto Neziḳin* is given correctly as one, containing thirty chapters. Compare T. B., *Bobo Ḳammo*, leaf 102*a*, *'Abodah Zarah*, 7*a*, and *Midrash Shemuel*, v.

[12] See p. 503, note 16.

[13] Also known under *Sheḥitath Ḳodoshim*.

predisposing for the contraction of impurities, Lev. xi. 34), in six chapters; (9) *Zabim* (Lev. xv. 2–33), in five chapters; (10) *Tebul Yom* (Num. xix. 19), in four chapters; (11) *Yadayim* (purification of the hands), in four chapters; (12) *'Okotsin* (stalks, peel, &c., of fruit), in three chapters.

11. *Editions.*—The editions of the *Mishnah*, whether as a book by itself or as contained in the Babylonian Talmud, are too numerous to be mentioned here. The *editio princeps* of the *Mishnah*, as a separate book, appeared (with Maimonides's commentary) at Naples in 1492 (see MAIMONIDES), and that as contained in the Babylonian Talmud at Venice in 1520–23, both in folio. As part of the Palestinian Talmud the *Mishnah* came out also at Venice, in 1523–24, folio. This Talmud, however, being defective, its *Mishnah* naturally is incomplete too (see p. 505); and it is, moreover, "corrected" by the scribe of 1288–89 (see Schiller-Szinessy, *Occasional Notices*, &c., i. pp. 8, 11). The syndics of the University Press of Cambridge have therefore laid the learned public under considerable obligations by publishing for the first time the complete original *Mishnah* on which the Palestinian Talmud rests, from the unique MS. preserved in the University Library.[1]

12. *Translations.*—There exist translations of the *Mishnah* in Latin, German, and English. (1) There is a Latin translation by the brothers Abendana (R. Ya'akob and R. Yitshak). The former was *Haham* (*Hakham, i.e.*, chief rabbi) of the Sepharadim in England, and the latter was teacher of Hebrew and Rabbinic at Cambridge and Oxford successively. Both brothers, correspondents in 1660 of Buxtorf, were fine Hebrew and Latin scholars (see Schiller-Szinessy, "The Abendanas," in *Jewish World* of December 5, 1879). This translation is preserved in the Cambridge University Library MS. Mm. 1. 4–8.[2] (2) The Abendanas' version was before Surenhusius when he compiled, from old and new materials, his Latin translation, which appeared (with the text of the *Mishnah* and the translation also of the commentaries of Maimonides and "Bertinoro") at Amsterdam in 1698–1703, folio. The great indebtedness of Surenhusius to the Abendanas is a fact either unknown to or ignored by the bibliographers.[3] (3) A German translation by Rabe came out in German letters at Onolzbach in 1760–63, 4to. (4) The version last-named was in the possession of the anonymous author of the translation, printed in Rabbinic letters, in the Vienna edition of the *Mishnah* with the commentary *Kaph Nahath*, 1817–35, 8vo. This author (or editor) silently "used" the work of his predecessor. (5) Both these translations were surpassed in German diction, as well as in correctness of rendering, by that which came out in Hebrew square letters at Berlin in 1832–34, 4to, and which, no doubt, belongs to J. M. Jost the historian. (6) The English translation which came out at London in 1843, 8vo, by De Sola and Raphael, extends only over eighteen treatises.

13. *Commentaries.*—The commentaries on the *Mishnah* are almost as numerous as the editions, and cannot therefore be specially enumerated here. The principal and the oldest, however, are the following. (1) The two Talmuds themselves, of which, at present,[4] the Babylonian is the only (and that but comparatively) perfect one, or at all events the more extensive of the two. It ought, however, to be stated, first, that the Palestinian Talmud has *Gemara* on the whole order *Zera'im*, whilst the Babylonian has it on the first "treatise" only of that order (*Berakhoth*), and, secondly, that the *Gemarath Shekalim* in the Babylonian Talmud is only borrowed from the Palestinian Talmud. (2) The commentaries on *Zera'im*, *Tohoroth*, &c., by Rabbenu Hai Gaon, who was the last, most learned, and in every way noblest of the Geonim.[5] He flourished in the 10th and 11th centuries. Part of the commentaries (viz., that on *Tohoroth*) has appeared in the collection *Kobets Ma'ase Yede Geonim*, &c. (Berlin, 1856, 8vo). (3) The commentary on various treatises of the B. Talmud, and indirectly on the *Mishnah*, by Rabbenu Gershom Meor Haggolah (the "Light of the *Diaspora*,"[6] flourished in the 10th and 11th centuries). Fragments of this commentary are incorporated in the ordinary Talmud editions (*e.g.*, *Nedarim*, 22*b*, &c.), but the greater part lies as yet in manuscript in various libraries. (4) The commentary of Rabbenu Hananeel, who lived at Kairawan (in Africa) in the 10th and 11th centuries. His commentary on the Talmud, and thus indirectly on the *Mishnah*, is now being published in the Vilna edition of the Babylonian Talmud.[7] (5) The commentary of Rashi (*ob.* 1105) in all those parts of the B. Talmud on which that "prince of commentators" wrote. Here ought to be mentioned also the separate *editio princeps* of this commentary as far as the *Mishnah* is concerned, which appeared at Leghorn in 1653–54, 8vo. (6) The supplements and additions to the commentary of Rashi by his son-in-law Rabbenu Yehudah b. Nathan (*e.g.*, T. B., *Makkoth*, 19*b*, &c.), and by his grandsons Rabbenu Shemuel b. Meir (*vulgo* Rashbam; see *Pesahim*, 99*b*, and *Bobo Bathro*, 29*a*, &c.) and Rabbenu Shema'yah b. Simhah of Vitri,[8] who interpreted the *Massekheth Middoth* before Rashi, his grandfather (see Schiller-Szinessy, *Catalogue of the Hebrew MSS.* preserved in the University Library of Cambridge, ii. p. 89). (7) The commentary on the whole *Mishnah* by MAIMONIDES (*q.v.*). (8) The commentary by R. Abraham b. David of Posquières (*vulgo* Rabad) on *'Eduyyoth* (see editions of the B. Talmud), *Kinnim* (with two other commentaries by Rabbenu Zerahyah Hallevi and R. Asher b. Yehiel, Constantinople, 1751, folio), and on many other *Mishnaiyyoth* of the orders *Zera'im* and *Tohoroth* (in his "strictures" on Maimonides, *Mishnah Torah*, books *Zera'im* and *Tohorah*). (9) The commentary of R. Shimshon of Sens (who, like the foregoing, was a contemporary and opponent of Maimonides) on the orders of *Zera'im* (with supplements taken from the works of the somewhat older R. Yitshak b. Malkitsedek) and *Tohoroth*.[9] (10) The commentary by R. Meir of Rothenburg (the celebrated captive of Rudolph of Hapsburg); see under (13) below. (11) The commentary by R. Asher b. Yehiel (a disciple of the foregoing, who died at Toledo in 1327) on twenty-one treatises of the orders i. and vi. (12) The commentary on the whole *Mishnah*, by Rabbenu 'Obadyah di Bertinoro (flourished in the 15th and 16th centuries), the editions of which are very numerous. (13) The commentary on the whole *Mishnah*, by R. Yomtob Lipmann Heller (flourished in 16th and 17th centuries). This famous teacher, rabbi in some of the greatest congregations of the Jews (Prague, Vladimir, and Cracow), incorporated much of the commentary of R. Meir of Rothenburg; compare under (10).

Mathnitho.

14. *Works Subsidiary and Auxiliary to the Mishnah.*—These may be summed up under the word *Mathnitho*. *Mathnitho* is ostensibly the Aramaic equivalent of the Hebrew *Mishnah*; in reality, however, it signifies and comprises, not merely everything which is understood under that name, but also *Boraitho* (in full, *Mathnitho Boraitho*), *i.e.*, four other works of the oral law, and many literary notices of Mishnic and pre-Mishnic times besides, which are scattered throughout the Talmuds and other early Rabbinic works.

Tosephto.

The first of these is *Tosephto*. As its name indicates, *Tosephto* is "Addition," *i.e.*, to the canonical *Mishnah*. All *Mishnah* teachers from time immemorial, notably R. 'Akibah and R. Yehudah Hannasi, left out, when they taught *Mishnah*, a large mass of kindred and explanatory matter, which they only occasionally and supplementarily mentioned, *i.e.*, when absolutely wanted. The chief collection of this additional matter, not incorporated in the system of the canonical *Mishnah*, is called *Tosephth* in Hebrew and *Tosephto* (or *Tosiphta* as some less correctly write it) in Aramaic. The Aramaic singular and the Hebrew plural occur already in the Talmuds and *Midrashim*.[10] *Tosephto* shares with the *Mishnah*, which it enlarges and explains, the number of orders and treatises, but not that of chapters, of which it has only 452. The oldest collection of Tosephtic matter, even as the oldest collection of Mishnic matter, is due to R. 'Akibah. But, whilst

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[1] See Mr W. H. Lowe's able edition of this grand work (*The Mishnah on which the Palestinian Talmud rests*, Cambridge, 1883, 8vo).

[2] According to Picciotto (*Sketches of Anglo-Jewish History*, London, 1875, 8vo, p. 55), R. Yitshak Abendana translated the *Mishnah* and its commentaries (Maimonides and "Bertinoro"?) also into Spanish.

[3] Surenhusius was also aided in his grand work by the books and notes of Guisius (in *Berakhoth*, *Peah*, *Demai*, *Kil'ayim*, *Shebi'ith*, *Terumoth*, and *Ma'aseroth*, i.–iii. 3), Schmid (in *Shabbath* and *'Erubin*), Houting (*Rosh Hasshanah*), Lund (*Ta'anith*), Otho (*Shekalim*), Wagenseil (*Sotah*), Cocceius (*Makkoth*), Fagius (*Aboth*), Arnoldi (*Tamid*), L'Empereur (*Middoth*), and Ulmann (*Zebahim* and *Karethoth*). But without the Abendanas Surenhusius could never have commenced, much less executed, the great task he had before him.

[4] For the probability that the missing parts of the Palestinian Talmud will one day come to light somewhere in the East, see Schiller-Szinessy in the *Academy*, February 23, 1878; *He-Chaluz*, xi.; and Steinschneider, *Handschriften-Verzeichnisse der königlichen Bibliothek zu Berlin*, ii., &c. (1878, 4to), p. 65, where a passage of Palestinian *Gemara* of *'Okotsin* is actually quoted.

[5] He was also a poet of no mean standing. See his *Musar Haskel* (or *Hassekhel*), *ed. princ.* Fano, 1505 (?), 4to.

[6] In the synod called together by Rabbenu Gershom, among several "ordinances" was also one that no Jew is allowed to marry more than one wife.

[7] His commentary on *Pesahim* appeared at Paris in 1868, and that on *Makkoth* at Leipsic in 1876, both in 8vo.

[8] These writers (together with Rabbenu Meir another son-in-law and Rabbenu Ya'akob another grandson of Rashi) are the first of the so-called Tosaphists, whose activity continued down to the early part of the 14th century.

[9] Whether the commentary on *Tamid* printed under his name, together with that of R. Asher b. Yehiel on the same treatise (Prague, 1725, 4to), is really his is still matter of dispute.

[10] See T. Y., *Shabbath*, viii. 1, &c.; T. B., *Synhedrin*, 86*a* and elsewhere; *Midrash Rabbah* on Ecclesiastes v. 8, &c. There can be little doubt that in some places the word תוספתא ought to be transliterated *Tosephotho* (*i.e.*, as plural).

the *Mishnah*, as a work, was first sifted by his disciple R. Meir, *Tosephto*, as a work, was first sifted by another disciple R. Nehemyah; and just as R. Meir's *Mishnah* was sifted again by *Rabbi* and others after him, and was not written down before the 6th century, so *Tosephto* was sifted again by R. Ḥiyya, R. Hosha'yah, and others, and was not written down in its entirety before the 6th century. It is no wonder, then, that it now contains matter of a considerably later age. *Tosephto* is not merely of great help for understanding the *Mishnah*, which is, in a certain sense, incomplete without it, but for the precise and exact knowledge of Jewish archæology and other sciences, and in its Agadic parts, of which there are many, for the Greek Scriptures also. Here ought also to be mentioned *Aboth de-Rabbi Nathan*, which is, no doubt, *Tosephto* to the *Mishnah* of *Aboth*. *Tosephto* used to be printed till within the last forty years [1] as an appendix to the *Riph*, *i.e.*, the *Hilekhoth Rab Alphes* (a compendium of the Talmud by R. Yitsḥak b. Ya'akob Al-Phesi, or Al-Phasi, *i.e.*, of Fez, *ob.* 1103), which appeared first with this appendix at Venice, 1521–22, folio. Here, however, it was not edited critically or printed with even ordinary care. But in the Vienna edition of the Babylonian Talmud (1860–72) it came out, for the first time, worthily after a MS. till then uncollated which is preserved in the Court Library. Dr Zuckermandel has since published it from the Erfurt and Vienna MSS., with collations.[2] A Latin translation of *Tosephto* (with the Hebrew text) is to be found, under the name of *Tosaphta*, in Blasius Ugolinus's *Thesaurus Antiquitatum Sacrarum* (xvii.–xx.). It comprises, however, only the orders *Zera'im*, *Mo'ed*, and *Ḳodoshim*, and came out at Venice in the years 1755–57, folio.

hilto. The second of these pieces of literature is *Mekhilto*. This word is the Aramaic equivalent of the Hebrew *Middah* (measure), and hence signifies mould, form, *i.e.*, of Scriptural exegesis, notably of part or parts of the Pentateuch. As such it might, of course, stand for any kind of commentary on any book of the Pentateuch, and have been composed by any one. And we find, indeed, that *Mekhilto* signified at one time a commentary on the books Exodus, Leviticus, Numbers, and Deuteronomy, either by R. Yishma'el or by R. 'Akibah,[3] at another time a commentary on Exodus, by R. Shime'on b. Yoḥai,[4] and at another time again a commentary on the last four books of Moses, by (Shime'on) Ben 'Azzai.[5] *Mekhilto* now, however, means a commentary on the greater part of Exodus, ascribed to R. Yishma'el (flourished in the 1st century); although, in reality, this teacher cannot have been the author of the book, seeing that his name is more than seventy times mentioned in it. The reason why the ancients called the book by his name is, no doubt, because the first words of the real work are *Amar Rabbi Yishma'el*. Like the other works of the "oral law," *Mekhilto* was not written down before the 6th century, a fact which accounts also, in part at least, for the loss of several portions of this commentary, which, at present, only extends from xii. 1 to xxv. 3, with several gaps between. That *Mekhilto* was once fuller than it is now we know, not only from a statement made by Maimonides and others, but from a MS. (Add. 394. 1, in the University Library of Cambridge, leaf 40*b*), where an extract is given by a Franco-German author of the 12th or 13th century. The Talmud knows the name *Mekhilto*, and actually quotes *Boraithoth* (non-canonical *Mishniyyoth*) which are to be found in our book; and yet the existing *Mekhilto* can scarcely have been known to the teachers of the Talmud. *Mekhilto* is by some called *Midrash* and by others *Mishnah*; both names are in a certain sense correct. It is *Midrash* in substance, inasmuch as it contains exegesis, and in form, inasmuch as it is subdivided into *Parshiyyoth* and follows the order of the Scriptural verses. But it is *Mishnah* in substance, inasmuch as it not only deals with the groundwork of the *Mishnah*, but consists of *Boraithoth* (non-canonical *Mishniyyoth*), and in form, inasmuch as it is, like the canonical *Mishnah*, divided into *Massekhtoth*. These latter are nine in number, and are called respectively (1) *Dephisha* (with 18 *Parshiyyoth* and 1 *Pethihto* or introduction), (2) *Beshallaḥ* (with 6 *Parshiyyoth* and 1 *Pethiḥto*), (3) *Deshiretha* (with 10 *Parshiyyoth*), (4) *Vayyassa'* (with 6 *Parshiyyoth*), (5) *'Amaleḳ* (with 2 *Parshiyyoth*), (6) *Yithro* (with 2 *Parshiyyoth*), (7) *Baḥodesh* (with 11 *Parshiyyoth*), (8) *Neziḳin* and *Kaspo* (with 20 *Parshiyyoth*), and (9) *Shabbetho* (with 2 *Parshiyyoth*—1 in the pericope *Ki thissa* and 1 in that of *Vayyaḳhel*). *Mekhilto* was published first at Constantinople in 1515, under the name of *Sepher Hammekhilto*, and in 1545 at Venice as *Midrash Hammekhilto*. In 1712 it appeared at Amsterdam with a commentary. In 1744 it appeared again at Venice with a Latin translation by Blasius Ugolinus (*Thes. Antiq. Sacr.*, xiv.). In 1801 it appeared at Leghorn with a different commentary. In 1844 it came out at Vilna with a new commentary. All these are in folio. The best and cheapest editions with commentaries are those by Weiss (1865) and Friedmann (1870), both printed at Vienna, and in 8vo.

The third of these pieces of literature is *Siphro*. Both Leviticus itself, because it is the most difficult of all Mosaic books, and the oldest Rabbinic commentary on it, because it is the most difficult of all commentaries on the Scriptures, have been from time immemorial known under the name of *Siphro* (*i.e.*, *the* Book).[6] This book and this commentary are also called *Torath Kohanim*, and the former is spoken of in the Talmud already as *Siphro debe Rab*.[7] This latter expression has led many great men (among others Maimonides)[8] to ascribe the authorship of this commentary to Rab (Abba Arikho, a nephew and disciple of R. Ḥiyya). But such a view is erroneous in the extreme, as the book is, so far as form and substance go, both older and later than Rab, paradoxical as this statement may appear. It is older in its origin and in its matter, for not merely do all the anonymous *Boraithoth* which are to be found in it belong to R. Yehudah b. Il'ai, a teacher of the 1st century, but one of the sons of Rabbi (of the 2d century) had actually taught another rabbi two-thirds of a third, *i.e.*, two-ninths, of this work.[9] It is later than Rab, for in it are found one "authority" and several "results" of much later date than that of this great Babylonian teacher.[10] The fact is, the word *Rab* in the phrase *Siphro debe Rab* is not a proper name at all, but simply stands for "teacher," and *debe Rab* thus signifies "of a school," a term used for any teacher and any school of any time. Although most of the *Boraithoth* which it contains are as old as the 1st century, this book as such cannot have been written down earlier than the 6th, in accordance with the treatment, in this respect, of all the other Halakhic works of the "oral law." *Siphro*, although it bears on the pericopes and verses of Leviticus, and is on account of this fact by many called a *Midrash*, is in reality *Mishnah*,[11]—a name borne out by the nature of its contents, which are mostly Mishnic, and sometimes represent actual canonical *Mishniyyoth*. *Siphro* exhibits a curious conglomeration of matter. It opens with the "Rules of the Interpretation of Scripture," ascribed to R. Yishma'el,—a *Boraitho* which, although important in itself, is not more important for this than for any other commentary on the Pentateuch. And this conglomerate nature shows itself even more strikingly in form; for *Siphro* contains as forms of division *Dibburim*, *Mekhilto*, *Parshiyyoth* (some of which mean pericopes, whilst others mean chapters), *Peraḳim*, and *Pisḳoth*. All this points, of course, to various divisions of the book made at various times. Whilst none of these divisions can be later than the 12th century,[12] the earliest is at least as old as the 2d, and belongs perhaps to the 1st.[13] *Siphro* is chiefly of importance for the understanding of the *Mishnah* of the orders *Ḳodoshim* and *Tohoroth* (which were, no doubt, the earliest *Mishniyyoth* put into "order"); but, whilst it is a sure help for the *Mishnah*, the *Mishnah* is no sure help for it: *Siphro* is a genuine specimen of the "oral law," inasmuch as it cannot be mastered without a teacher. Owing to the difficulty of understanding it, *Siphro* has not been often studied, and consequently not often printed. The *editio princeps* is of 1545; the second edition with the commentary *Ḳorban Aharon* is of 1609–11, both at Venice. The third edition with the just-named commentary is of 1702, and came out at Dessau. The fourth edition, with a Latin translation, is to be found in Blasius Ugolinus's *Thesaurus Antiquitatum Sacrarum*, &c., Venice, 1744 (vol. xiv.). All these are in folio. The fifth edition, with the commentary *'Azarath Ḳohanim* (vol. i.), appeared at Vilna, 1845, 4to. The sixth edition, with the commentary *'Asirith Haephah*, appeared at Lemberg, 1848, folio. The seventh edition, with the commentary *Hattorah Vehам-Mitsvah*, appeared at Bucharest, 1860, 4to. The eighth edition, with the commentary of R. Abraham b. David of Posquières, &c., appeared at Vienna, 1862; and the ninth edition, with the commentary by R. Shimshon of Sens, appeared at Warsaw, 1866, both in folio. Siphro.

The fourth of these pieces of literature is *Siphere*. *Siphere*, or *Siphere debe Rab*, which in earlier times certainly included the oldest Rabbinic commentaries on Exodus, Numbers, and Deuteronomy (and perhaps also that on Leviticus), means now the oldest Rabbinic commentary on the last two books of Moses only. Siphere.

[1] That on the order *Zera'im* came out at Vilna in 1799, 4to; but in its entirety it came only out between 1837, 1841, and 1871, folio.

[2] Issued at Pasewalk and Treves from 1877 to 1882, 8vo.

[3] See Maimonides's preface to the *Mishneh Torah*.

[4] See Naḥmanides's commentary on the Pentateuch (on Gen. xlix. 31).

[5] See *Yuḥasin Hasshalem* (ed. Filipowski, London and Edinburgh, 1857. 8vo), p. 30, col. 2.

[6] See T. B., *Berakhoth*, 18*b*, and Rashi, *in loco*. The *Siphro* said here to have been studied by Benaiah the son of Jehoiada may well have been our Leviticus, though of course it cannot have been the *Siphro* with which we are here concerned.

[7] *Ibid.*

[8] Preface to *Mishneh Torah*.

[9] See T. B., *Ḳiddushin*, 33*a*.

[10] See the pericope *Ḳedoshim*, vi.

[11] Its original founder (R. Yehudah b. Il'ai) identifies *Mishnah* and *Midrash*, T. B., *Ḳiddushin*, 49*a*.

[12] They were known to R. Abraham b. David (Rabad).

[13] T. B., *Ḳiddushin*, 33*a*.

Both books are divided into *Piskoth* (paragraphs), of which *Siphere* on Numbers has 161, whilst that on Deuteronomy has 357. The ancient division into *Boraithoth* cannot now be accurately traced. The work commences now at Numbers v. 1, and goes to the end of Deuteronomy. The passages anonymously given in *Siphere* are ascribed by the Babylonian Talmud[1] to R. Shime'on b. Yohai, the favourite disciple of R. 'Akibah, and the reputed author of the *Zohar*. But although he is no doubt the virtual author of *Siphere*, seeing that most *Boraithoth* which are to be found therein are his, he cannot be, technically speaking, its author. For, in the first place, he is not only repeatedly named in the book, but several times actually contradicted by others; and, secondly, there are several passages, anonymously given, in the book, which can only be the result of "Talmudic" study, and must be consequently posterior to the composition of the Talmud. The fact is that *Siphere*, like the other works of the "oral law," was not written down before the 6th century. It ought to be mentioned here that the rabbis of the 11th, 12th, and 13th centuries, and even somewhat later, speak also of another *Siphere* which they variously designate as *Siphere Panim Sheni*, *Siphere shel Panim Sheni*, *Siphere Bemidbar Sinai*, *Siphere Zutta*, and *Siphere* simply. To judge from the extracts which have come down to us, that work must not only have been of much later date, but also of far less value than the work in our hands. *Siphere* appeared for the first time in 1545, and with a Latin translation by Blasius Ugolinus, in his *Thesaurus*, &c. (vol. xv.), in 1744,—both at Venice, and in folio. The third edition appeared at Hamburg in 1789, and the fourth at Sulzbach in 1802, both in 4to. The fifth edition, with the commentary *Zera' Abraham*, appeared in two volumes, of which the first was printed at Dyhernfurt in 1811 and the second at Radawell in 1820, both in folio. The sixth and best edition is that of Friedmann (Vienna, 1864), and the seventh is that of Lemberg, 1866, both in 8vo.

Boraitho. There is also a fifth piece of Mishnic literature known specially by the name *Boraitho*. Besides the *Boraithoth* constituting *Tosephto*, *Mekhilto*, *Siphro*, and *Siphere*, there are hundreds of other *Boraithoth* to be found scattered about in both Talmuds. These are, however, mere fragments of the vast *Mishnayoth* (entire Mishnic works[2]) composed by Bar Kappara, Rabbi Hiyya, and hundreds of other teachers, which in course of time must have perished. There is, however, enough left of the *Mishnah*, canonical and non-canonical, to prove the correctness of the cabbalistic remark that *Mishnah* is the equivalent of *Neshamah* (soul). This is no mere trifling based on the fact that the two words (משנה, נשמה) accidentally consist of the same letters; it is rather an enunciation of an intrinsic truth: what the soul (*Neshamah*) is to the body, the *Mishnah* is to Mosaism. The soul gives life to the body, and the *Mishnah* gives life to the Pentateuch. For the letter killeth, but the spirit giveth life! (S. M. S.-S.)

MISKOLCZ, capital of the Cis-Tisian county of Borsod, Hungary (48° 6′ N. lat., 20° 49′ E. long.), is picturesquely situated in a valley watered by the Szinva, 90 miles northeast from Budapest, with which, as also with Debreczen and Kássa (Kaschau), it is directly connected by railway. Miskolcz is one of the most thriving provincial towns in the kingdom, and has many fine buildings, including Roman Catholic, Greek Catholic, Lutheran, and Calvinist churches and schools, a Minorite convent, synagogue, Hungarian theatre, hospital, royal and circuit courts of law, salt and tax offices, and the administrative bureaus for the county. There are manufactories of snuff, porcelain, boots and shoes, and prepared leather, and both steam and water mills. The trade is chiefly in grain, wheaten flour, wine, fruit, cattle, hides, honey, wax, and the agricultural products of the neighbourhood. The great fairs, held five times a year, are much resorted to by strangers from a distance. Not far from the town are stone quarries and iron mines. At the end of 1880 the (civil) population amounted to 24,343, of whom the majority were Magyars by nationality.

During the 16th and 17th centuries Miskolcz suffered much from the desolating hordes of Ottomans who then ravaged the country, as also from the troops of various Transylvanian princes and leaders, especially those of George Rákóczy and Emeric Tökölyi. In 1781, 1843, and 1847 it was devastated by fire, and on the 30th August 1878 a great portion of the town was laid in ruins by a terrific storm. (See HUNGARY, vol. xii. p. 374.)

MISREPRESENTATION. See FRAUD.

[1] *Synhedrin*, 86*a*.

[2] According to T. B., *Hagigah*, 14*a*, there existed at one time no less than six or seven hundred *Mishnah* orders.

MISSAL,[3] the book containing the liturgy, or office of the mass, of the Latin Church. This name (*e.g.*, Missale Gothicum, Francorum, Gallicanum Vetus) began to supersede the older word *Sacramentary* (Sacramentarium, Liber Sacramentorum) from about the middle of the 8th century. At that period the books so designated contained merely the fixed canon of the mass or consecration prayer (actionem, precem canonicam, canonem actionis), and the variable collects, secretæ or orationes super oblata, prefaces, and post-communions for each fast, vigil, festival, or feria, of the ecclesiastical year; for a due celebration of the Eucharist they required accordingly to be supplemented by other books, such as the *Antiphonarium*, afterwards called the *Graduale*, containing the proper antiphons (introits), responsories (graduals), tracts, sequences, offertories, communions, and other portions of the communion service designed to be sung by the schola or choir, and the *Lectionarium* (or *Epistolarium* and *Evangelistarium*) with the proper lessons. Afterwards missals began to be prepared containing more or less fully the antiphons and lessons as well as the prayers proper to the various days, and these were called *missalia plenaria*. All modern missals are of this last description. The *Missale Romanum ex decreto SS. Concilii Tridentini restitutum*, now in almost exclusive use throughout all the churches of the Latin obedience, owes its present form to the council of Trent, which among its other tasks undertook the preparation of a correct and uniform liturgy, and entrusted the work to a committee of its members. This committee had not completed its labours when the council rose, but the pope was instructed to receive its report when ready and to act upon it. The "reformed missal" accordingly was promulgated by Pius V. on July 14, 1570, and its universal use enjoined on all branches of the Catholic Church, the only exceptions allowed being in the case of churches having local and independent liturgies which had been kept in unbroken use for at least two centuries.[4] It has subsequently undergone slight revisions under Clement VIII. (1604) and Urban VIII. (1634); and various new masses, both obligatory and permissive, universal and local, have been added by the competent authority. Although the Roman is very much larger in bulk than any other liturgy, it need hardly be explained that the communion office to which it relates is not in itself inordinately long. By much the greater part of it is contained in the "ordinary" and "canon" of the mass, usually placed about the middle of the missal, and occupies, though in large type, only a few pages in any printed copy. The work owes its bulk and complexity to two circumstances. On the one hand, in the celebration of the sacrifice of the mass practically nothing is left to the impulse or discretion of the officiating priest; everything—what he is to say, the tone and gestures with which he is to say it, the cut and colour of the robe he is to wear—is carefully prescribed either in the general rubrics prefixed to the text, or in the running rubrics which accompany it.[5] On the other hand, the Roman, like all the Western liturgies, is distinguished

[3] *Missalis* (sc., *liber*), *Missale*, from *Missa*; see vol. viii. p. 652.

[4] The English missal consequently continued to be used by English Catholics until towards the end of the 17th century, when it was superseded by the Roman through Jesuit influence. The Gallican liturgy held its ground until much more recently, but has now succumbed under the Ultramontanism of the bishops.

[5] In all the older liturgies the comparative absence of rubrics is conspicuous and sometimes perplexing. It is very noticeable in the Roman *Sacramentaries*, but the want is to some extent supplied by the very detailed directions for a high pontifical mass in the various texts of the *Ordo Romanus* mentioned below. That there was no absolutely fixed set of rubrics in use in France during the 8th century is shown by the fact that each priest was required to write out an account of his own practice ("libellum ordinis") and present it for approbation to the bishop in Lent (see Baluze, *Cap. Reg. Franc.*, i. 824, quoted in Smith's *Dict. of Chr. Antiq.*, ii. 1521).

from those of the Eastern Church by its flexibility. Partly by conscious effort, no doubt, but partly also by happy accident, a well-marked distinctive character has been given in one or all of the above-mentioned respects to the office for each ecclesiastical season, for each fast or festival of the year, almost for each day of the week; and provision has also been made of a suitable communion service for many of the special and extraordinary occasions both of public and of private life. This richness of variety is seen not only in the collects but also in the lessons and antiphonal parts of the service, passages of Scripture in the selection and collocation of which an exquisite delicacy of religious and æsthetic instinct has been for the most part strikingly shown.

The different parts of the Roman communion office are not all of the same antiquity. Its essential and characteristic features are most easily caught, and their rationale best understood, by reference to the earliest *Sacramentaries* (particularly the Gregorian, which was avowedly the basis of the labours of the Tridentine committee), to the Gregorian *Antiphonary*, and to the oldest redaction of the *Ordo Romanus*.[1] The account of the mass (qualiter Missa Romana celebratur) as given by the *Sacramentarium Gregorianum* is to the effect that there is in the first place "the *Introit* according to the time, whether for a festival or for a common day; thereafter *Kyrie Eleison*. (In addition to this *Gloria in Excelsis Deo* is said if a bishop be [the celebrant], though only on Sundays and festivals; but a priest is by no means to say it, except only at Eastertide. When there is a litany (quando letania agitur) neither *Gloria in Excelsis* nor *Alleluia* is sung.) Afterwards the *Oratio* is said, whereupon follows the *Apostolus*, also the *Gradual* and *Alleluia*. Afterwards the *Gospel* is read. Then comes the *Offertorium*,[2] and the *Oratio super oblata* is said." Then follow the *Sursum Corda*, the *Preface*, *Canon*, Lord's Prayer and "embolism" (ἐμβόλισμα or insertion, *Libera nos, Domine*), given at full length precisely as they still occur in the Roman missal.

In every liturgy of all the five groups a passage similar to this occurs, beginning with *Sursum Corda*, followed by a *Preface* and the recitation of the *Sanctus* or Angelic Hymn. The "canon" or consecration prayer, which in all of them comes immediately after, invariably contains our Lord's words of institution, and (except in the Nestorian liturgy) concludes with the Lord's Prayer and "embolism." But within this framework there are certain differences of arrangement, furnishing marks by which the various groups of liturgies can be classified (see vol. xiv. p. 709 *sq.*). Thus it is distinctive of the liturgy of Jerusalem that the "great intercession" for the quick and the dead follows the words of institution and an Epiklesis (ἐπίκλησις τοῦ πνεύματος ἁγίου) or petition for the descent of the Holy Spirit upon the gifts; in the Alexandrian the "great intercession" has its place in the *Preface*; in the East Syrian it comes between the words of restitution and the Epiklesis; in the Ephesine it comes before the *Preface*; while in the Roman it is divided into two, the commemoration of the living being before, and that of the dead after, the words of institution. Other distinctive features of the Roman liturgy are (1) the position of the "Pax" after the consecration, and not as in all the other liturgies at a very early stage of the service, before the *Preface* even; and (2) the absence of the Epiklesis common to all the others.[3]

[1] For the genealogical relationships of the Roman with other liturgies, the reader is referred to the article LITURGY (vol. xiv. 706 *sq.*), where some account is also given of the three *Sacramentaries*. For the doctrines involved in the "sacrifice of the mass," see EUCHARIST, vol. viii. p. 650 *sq.*

[2] Some editions do not mention the Offertory here.

[3] This was one of the points discussed at the council of Florence, and Cardinal Bessarion for a time succeeded in persuading the Greeks to give up the Epiklesis.

The words of its "canonical prayer" are of unknown antiquity; they are found in the extant manuscripts of the *Sacramentarium Gelasianum*, and were already old and of forgotten authorship in the time of Gregory the Great, who, in a letter to John, bishop of Syracuse (*Registr. Epist.*, vii. 64), speaks of it as "the prayer composed by a 'scholastic'" (precem quam scholasticus composuerat). The same letter is interesting as containing Gregory's defence, on the ground of ancient use, of certain parts of the Roman ritual to which the bishop of Syracuse had taken exception as merely borrowed from Constantinople. Thus we learn that, while at Constantinople the *Kyrie Eleison* was said by all simultaneously, it was the Roman custom for the clergy to repeat the words first and for the people to respond, *Christe Eleison* being also repeated an equal number of times. Again, the Lord's Prayer was said immediately after the consecration aloud by all the people among the Greeks, but at Rome by the priest alone.

The somewhat meagre and imperfect liturgical details furnished by the *Sacramentarium Gregorianum* are supplemented in a very full and interesting manner by the successive texts of the *Ordo Romanus*, the first of which dates from about the year 730. The ritual they enjoin is that for a pontifical high mass in Rome itself; but the differences to be observed by a priest "quando in statione facit missas" are comparatively slight. Subjoined is a précis of *Ordo Romanus I.*

It is first of all explained that Rome has seven ecclesiastical regions, each with its proper deacons, subdeacons, and acolytes. Each region has its own day of the week for high ecclesiastical functions, which are celebrated by each in rotation. [This accounts for the Statio ad S. Mariam Majorem, ad S. Crucem in Jerusalem, ad S. Petrum, &c., prefixed to most of the masses in the *Gregorian Sacramentary*, and still retained in the "Proprium de Tempore" of the Roman missal.] The regulations for the assembling and marshalling of the procession by which the pontiff is met and then escorted to the appointed station are minutely given, as well as for the adjustment of his vestments "ut bene sedeant," when the sacristy has been reached. He does not leave the sacristy until the *Introit* has been begun by the choir in the church. Before the *Gloria* he takes his stand at the altar, and after the *Kyrie Eleison* has been sung (the number of times is left to his discretion) he begins the *Gloria in Excelsis*, which is taken up by the choir. During the singing he faces eastward; at its close he turns round for a moment to say "Pax vobis," and forthwith proceeds to the *Oratio*.[4] This finished, all seat themselves in order while the subdeacon ascends the ambo and reads [the *Epistle*]. After he has done, the cantor with his book (cantatorio) ascends and gives out the response (*Responsum*) with the *Alleluia* and *Tractus* in addition if the season calls for either. The deacon then silently kisses the feet of the pontiff and receives his blessing in the words "Dominus sit in corde tuo et in labiis tuis." Preceded by acolytes with lighted candles and subdeacons burning incense, he ascends the ambo, where he reads the *Gospel*. At the close, with the words "Pax tibi" and "Dominus vobiscum," the pontiff,[5] after another *Oratio*, descends to the "senatorium" accompanied by certain of the inferior clergy, and receives in order the oblations of the rulers (oblationes principum), the archdeacon who follows taking their "amulas" of wine and pouring them into a larger vessel; similar offerings are received from the other ranks and classes present, including the women. This concluded, the pontiff and archdeacon wash their hands, the offerings being meanwhile arranged by the subdeacons on the altar, and water, supplied by the leader of the choir (archiparaphonista), being mingled with the wine. During this ceremony the schola have been engaged in singing the *Offertorium*; when all is ready the pontiff signs to them to stop, and enters upon the *Preface*, the subdeacons giving the responses. At the Angelic Hymn (*Sanctus*) all kneel and continue kneeling, except the pontiff, who rises alone and begins the *Canon*. At the words "per quem hæc omnia" the archdeacon lifts the cup with the oblates, and at "Pax Domini sit semper vobiscum" he gives the peace to the clergy in their order, and to the laity. The pontiff then breaks off a particle from the consecrated bread and lays it upon the altar; the rest he places on the paten held by the deacon. It is then distributed while *Agnus Dei* is sung. The pontiff in communicating puts the particle into the cup, saying, "Fiat commixtio et consecratio corporis et sanguinis Domini nostri Jesu Christi accipientibus nobis in vitam æternam." Those present communicate in their order under this species also.

[4] Quam collectam dicunt, *Ord. Rom. II.*

[5] After singing "Credo in unum Deum," *Ord. Rom. II.*

As the pontiff descends into the senatorium to give the communion, the schola begins the communion *Antiphon*, and continues singing the *Psalm* until, all the people having communicated, they receive the sign to begin the *Gloria*, after which, the verse having been again repeated, they stop. The celebrant, then, facing eastward, offers the *Oratio ad Complendum*, which being finished the archdeacon says to the people, "Ite, missa est," they responding with "Deo gratias."

To complete our idea of the Roman communion office as it was prior to the end of the 8th century we must now turn to the Gregorian *Antiphonarius sive Gradualis Liber ordinatus per circulum anni*, which as its name implies contains those variable portions of the mass which were intended to be sung by the schola or choir. It gives for each day for which a proper mass is provided—(1) the *Antiphona* (Antiphona ad Introitum) and *Psalmus*; (2) the *Responsorium* and *Versus*, with its *Alleluia* and *Versus*; (3) the *Offertorium* and *Versus*; (4) the *Communio* and *Psalmus*. Some explanation of each of these terms is necessary. (1) The word *Antiphon* (ἀντίφωνον, Old English *Antefn*, English *Anthem*) in its ecclesiastical use has reference to the very ancient practice of relieving the voices of the singers by dividing the work between alternate choirs. In one of its most usual meanings it has the special signification of a sentence (usually scriptural) constantly sung by one choir between the verses of a psalm or hymn sung by another. According to the Roman liturgiologists it was Pope Celestine who enjoined that the Psalms of David should be sung (in rotation, one presumes) antiphonally before mass; in process of time the antiphon came to be sung at the beginning and end only, and the psalm itself was reduced to a single verse. In the days of Gregory the Great the introit appears to have been sung precisely as at present,—that is to say, after the antiphon (proper and *par excellence*), the *Psalmus* with its *Gloria*, then the antiphon again. (2) The *Responsorium*, like the Greek antiphon, derives its name from the responsive manner of singing. As introduced between the epistle and gospel it was probably at first a comparatively long passage, usually an entire psalm or canticle, originally given out by the cantor from the steps from which the epistle had been read (hence the later name *Graduale*), the response being taken up by the whole choir. (3) The *Offertorium* and *Communio* correspond to the "hymn from the book of Psalms" mentioned by early authorities (see, for example, Augustine, *Retr.*, ii. 11; *Ap. Const.*, viii. 13) as sung before the oblation and also while that which had been offered was being distributed to the people. A very intimate connexion between these four parts of the choral service can generally be observed; thus, taking the first Sunday in the ecclesiastical year, we find both in the *Antiphonary* and in the modern *Missal* that the antiphon is Ps. xxv. 1–3, the psalmus Ps. xxv. 4, the responsorium (graduale) and versus Ps. xxv. 3 and xxv. 4, the offertorium and versus Ps. xxv. 1–3 and Ps. xxv. 5. The communio is Ps. lxxxv. 12, one of the verses of the responsorium being Ps. lxxxv. 7. In the selection of the introits there are also traces of a certain rotation of the psalms in the Psalter having been observed.

The first pages of the modern Roman missal are occupied with the *Calendar* and a variety of explanations relating to the year and its parts, and the manner of determining the movable feasts. The general rubrics (*Rubricæ Generales Missalis*) follow, explaining what are the various kinds of mass which may be celebrated, prescribing the hours of celebration, the kind and colour of vestments to be used, and the ritual to be followed (ritus celebrandi missam), and giving directions as to what is to be done in case of various defects or imperfections which may arise. The *Præparatio ad Missam*, which comes next, is a short manual of devotion containing psalms, hymns, and prayers to be used as opportunity may occur before and after celebration. Next comes the proper of the season (*Proprium Missarum de Tempore*), occupying more than half of the entire volume. It contains the proper introit, collect (one or more), epistle, gradual (tract or sequence), gospel, offertory, secreta (one or more), communion, and post-communion for every Sunday of the year, and also for the festivals and ferias connected with the ecclesiastical seasons, as well as the offices peculiar to the ember days, Holy Week, Easter, and Whitsuntide. Between the office for Holy Saturday and that for Easter Sunday the ordinary of the mass (*Ordo Missæ*), with the solemn and proper prefaces for the year, and the canon of the mass are inserted. The proper of the season is followed by the proper of the saints (*Proprium Sanctorum*), containing what is special to each saint's day in the order of the calendar, and by the *Commune Sanctorum*, containing such offices as the common of one martyr and bishop, the common of one martyr not a bishop, the common of many martyrs in paschal time, the common of many martyrs out of paschal time, and the like. A variety of masses to be used at the feast of the dedication of a church, of masses for the dead, and of votive masses (as for the sick, for persons journeying, for bridegroom and bride) follow, and also certain benedictions. Most missals have an appendix also containing certain local masses of saints to be celebrated "ex indulto apostolico."

Masses fall into two great subdivisions:—(1) ordinary or regular (secundum ordinem officii), celebrated according to the regular rotation of fast and feast, vigil and feria, in the calendar; (2) extraordinary or occasional (extra ordinem officii), being either "votive" or "for the dead," and from the nature of the case having no definite time prescribed for them. Festival masses are either double, half-double, or simple, an ordinary Sunday mass being a half-double. The difference depends on the number of collects and secretæ; on a double only one of each is offered, on a half-double there are two or three, and on a simple there may be as many as five, or even seven, of each. Any mass may be either high (missa solennis) or low (missa privata). The distinction depends upon the number of officiating clergy, certain differences of practice as to what is pronounced aloud and what inaudibly, the use or absence of incense, certain gestures, and the like. Solitary masses are forbidden; there must be at least an acolyte to give the responses. The vestments prescribed for the priest are the amice, alb, cingulum or girdle, maniple, stole, and chasuble (planeta); see COSTUME, vol. vi. p. 462. There are certain distinctions of course for a bishop or abbot. The colour of the vestments and of the drapery of the altar varies according to the day, being either white, red, green, violet, or black. This last custom does not go much further back than Innocent III., who explains the symbolism intended.

Subjoined is an account of the manner of celebrating high mass according to the rite at present in force.

1. The priest who is to celebrate, having previously confessed (if necessary) and having finished matins and lauds, is to seek leisure for private prayer (fasting) and to use as he has opportunity the "prayers before mass" already referred to. How the robing in the sacristy is next to be gone about is minutely prescribed, and prayers are given to be used as each article is put on. The sacramental elements having previously been placed on the altar or on a credence table, the celebrant enters the church and takes his stand before the lowest step of the altar, having the deacon on his right and the subdeacon on his left. After invoking the Trinity (In nomine Patris, &c.) he repeats alternately with those who are with him the psalm "Judica me, Deus," which is preceded in the usual way by an antiphon (Introibo ad altare Dei), and followed also by the Gloria and Antiphon.[1] The versicle "Adjutorium nostrum," with its

[1] This antiphon is not to be confounded with the Antiphona ad Introitum further on. This use of the 43d Psalm goes as far back at least as the end of the 11th century, being mentioned by Micrologus (1080). It is omitted in masses for the dead and during Holy Week.

response "Qui fecit," is followed by the "Confiteor,"[1] said alternately by the priest and by the attendants, who in turn respond with the prayer for divine forgiveness, "Misereatur." The priest then gives the absolution ("Indulgentiam"), and after the versicles and responses beginning "Deus, tu conversus" he audibly says, "Oremus," and ascending to the altar silently offers two short prayers, one asking for forgiveness and liberty of access through Christ, and another indulgence for himself "through the merits of thy saints whose relics are here." Receiving the thurible from the deacon he incenses the altar, and is thereafter himself incensed by the deacon. He then reads the Introit, which is also sung by the choir; the "Kyrie Eleison" is then said, after which the words "Gloria in Excelsis"[2] are sung by the celebrant and the rest of the hymn completed by the choir.

2. Kissing the altar, and turning to the people with the formula "Dominus vobiscum," the celebrant proceeds with the collect or collects proper to the season or day, which are read secretly. The epistle for the day is then read by the subdeacon, and is followed by the gradual, tract, alleluia, or sequence, according to the time.[3] This finished, the deacon places the book of the gospels on the altar, and the celebrant blesses the incense. The deacon kneels before the altar and offers the prayer "Munda cor meum," afterwards takes the book from the altar, and kneeling before the celebrant asks his blessing, which he receives with the words "Dominus sit in corde tuo." Having kissed the hand of the priest, he goes accompanied by acolytes with incense and lighted candles to the pulpit, and with a "Dominus vobiscum" and minutely prescribed crossings and incensings gives out and reads the gospel for the day, at the close of which "Laus tibi, Christe" is said, and the book is brought to the celebrant and kissed with the words "Per evangelica dicta deleantur nostra delicta." The celebrant then standing at the middle of the altar sings the words "Credo in unum Deum," and the rest of the Nicene creed is sung by the choir.[4]

3. With "Dominus vobiscum" and "Oremus" the celebrant proceeds to read the Offertory, which is also sung by the choir. This finished he receives the paten with the host from the deacon, and after offering the host with the prayer beginning "Suscipe, Sancte Pater" places it upon the corporal. The deacon then ministers wine and the subdeacon water, and before the celebrant mixes the water with the wine he blesses it in the prayer "Deus qui humanæ." He then takes the chalice, and having offered it ("Offerimus tibi, Domine") places it upon the corporal and covers it with the pall. Slightly bowing over the altar, he then offers the prayer "In spiritu humilitatis," and, lifting up his eyes and stretching out his hands, proceeds with "Veni sanctificator." After blessing the incense ("Per intercessionem beati Michaelis archangeli") he takes the thurible from the deacon and incenses the bread and wine and altar, and is afterwards himself incensed as well as the others in their order. Next going to the epistle side of the altar he washes his fingers as he recites the verses of the 26th Psalm beginning "Lavabo." Returning and bowing before the middle of the altar, with joined hands he says, "Suscipe, sancta Trinitas," then turning himself towards the people he raises his voice a little and says, "Orate, fratres" ("that my sacrifice and yours may be acceptable to God the Father Almighty"), the response to which is "Suscipiat Dominus sacrificium de manibus tuis," &c. He then recites the secret prayer or prayers, and at the end says, with an audible voice, "Per omnia sæcula sæculorum" (℟. "Amen").

4. Again saluting with a "Dominus vobiscum," he lifts up his hands and goes on to the "Sursum Corda" and the rest of the Preface. A different intonation is given for each of the prefaces.[5] At the Sanctus the handbell is rung. If there is a choir the Sanctus is sung while the celebrant goes on with the Canon.[6] After the words of consecration of the wafer, which are said "secretly, distinctly, and attentively," the celebrant kneels and adores the host, rising elevates it, and replacing it on the corporal again adores it (the bell meanwhile being rung).[7] The same rite is observed when the chalice is consecrated. Immediately before the Lord's Prayer, at the words "per ipsum et cum ipso et in ipso," the sign of the cross is made three times over the chalice with the host, and towards the close of the "embolism" the fraction of the host takes place. After the words "Pax Domini sit semper vobiscum" the emission of the particle into the cup takes place with the words "Hæc commixtio et consecratio," &c. The celebrant then says the Agnus Dei three times.

5. While the choir sings the Agnus Dei and the Communion, the celebrant proceeds, still "secrete," with the remainder of the office, which though printed as part of the canon is more conveniently called the Communion and Post-communion. After the prayer for the peace and unity of the church ("Domine Jesu Christe, qui dixisti") he salutes the deacon with the kiss of peace, saying, "Pax tecum"; the subdeacon is saluted in like manner, and then conveys the "pax" to the rest of the clergy who may be assisting. The celebrant then communicates under both species with suitable prayers and actions, and afterwards administers the sacrament to the other communicants if there be any. Then while the wine is poured into the cup for the first ablution he says, "Quod ore sumpsimus"; having taken it he says, "Corpus tuum, Domine." After the second ablution he goes to the book and reads the Communion. Then turning to the people with "Dominus vobiscum" he reads the Post-communion (one or more); turning once more to the congregation he uses the old dismissal formula "Dominus vobiscum" (℟. Et cum spiritu tuo), and "Ite, missa est" [or "Benedicamus Domino," in those masses from which "Gloria in Excelsis" has been omitted] (℟. Deo Gratias). Bowing down before the altar he offers the prayer "Placeat tibi, sancta Trinitas," then turning round he makes the sign of the cross over the congregation with the words of the benediction ("Benedicat").[8] He then reads the passage from the gospel of John beginning with "In principio erat Verbum," or else the proper gospel of the day.[9] (J. S. BL.)

MISSIONS. The history of Christian missions may, for practical purposes, be best divided into three chief periods—(1) the primitive, (2) the mediæval, and (3) the modern. None of these periods can be neglected, for they have an intimate connexion with each other, and illustrate the activity respectively of individuals, of the church in her corporate capacity, and of societies.

1. *The Primitive Period.*

Christian missions had their origin in the example and the command of our Lord Himself (Matt. xxviii. 19); and the unparalleled boldness on the part of the Founder of Christianity, which dared to anticipate for the Christian faith a succession of efforts which should never cease to cause its propagation to be undertaken as "a distinct and direct work," has been justified by the voice of history.[10] Whereas other religions have spread from country to country as component parts of popular opinion, have travelled with migration or conquest, have passed in the train of things and by the usual channels of communication, the first foundations of the church had hardly been laid before individual missionary activity marked the life of each one of the circle of the apostles.

Of the actual details of their labours we have been permitted to know but little. Three only of the immediate followers of the Saviour have any conspicuous place in the apostolic records, and the most illustrious in the whole domain of missionary activity, St Paul, did not belong to the original twelve. His activity took the form of journeys and voyages, chiefly to large towns, where his message found a point of contact either with the Jewish synagogue or the aspirations of the Gentile world. The result of his labours and of those of his successors

[1] A form very similar to the present is given by Micrologus, and it is foreshadowed even in liturgical literature of the 8th century.

[2] During Lent and Advent, and in masses for the dead, this is omitted. In low masses it is of course said, not sung (if it is to be said). It may be added that this early position of the *Gloria in Excelsis* is one of the features distinguishing Roman from Ephesine use.

[3] The tract is peculiar to certain occasions, especially of a mournful nature, and is sung by a single voice. By a sequence is understood a more or less metrical composition, not in the words of Scripture, having a special bearing on the festival of the day. See, for example, the sequence, "Lauda Sion Salvatorem," on Corpus Christi day.

[4] On certain days the *Credo* is omitted.

[5] Now eleven; they were at one time much more numerous.

[6] The approved usage appears to be in that case that it is sung as far as "Hosanna in Excelsis" before the elevation, and "Benedictus qui venit" is reserved till afterwards. In France it was a very common custom, made general for a time at the request of Louis XII., to sing "O salutaris hostia" at the elevation.

[7] The history of the practice of elevating the host is somewhat obscure. It seems to have arisen out of the custom of holding up the oblations, as mentioned in the *Ordo Romanus* (see above). The elevation of the host, as at present practised, was first enjoined by Pope Honorius III. The use of the handbell at the elevation is still later, and was first made general by Gregory XI.

[8] The benediction is omitted in masses for the dead.

[9] The reading of the passage from John on days which had not a proper gospel was first enjoined by Pius V.

[10] Davison, *On Prophecy*, p. 278.

was that towards the middle of the 2d century the church had gradually extended its conquests through Asia Minor, Greece, Italy, southern Gaul, and northern Africa.[1] Ecclesiastical history can tell but little of the church's earliest teachers, and the infancy of many of the primitive congregations is wrapped in hopeless darkness. Whatever was effected was due to the evangelizing labours of individual bishops and clergy, who occupied themselves "in season and out of season," and toiled zealously and effectively in the spread of the church, though leaving no record of their devotion. Amongst the most distinguished representatives of this individual activity in the 4th and 5th centuries may be mentioned Ulfila, the "apostle of the Goths," about 325; Frumentius, a bishop of Abyssinia, about 327; Chrysostom, who founded at Constantinople in 404 A.D. an institution in which Goths might be trained to preach the gospel to their own people;[2] Valentinus, the "apostle of Noricum," about 440; and Honoratus, who from his monastic home in the islet of Lerins, about 410, sent forth numerous labourers to southern and western Gaul, to become the leading missionaries of their day among the masses of heathendom in the neighbourhood of Arles, Lyons, Troyes, Metz, and Nice.

2. *The Mediæval Period.*

With the 5th century the church found a very different element proposed to her missionary energies and zeal. Her outposts of civilization had scarcely been planted when she was confronted with numberless hordes which had long been gathering afar off in their native wilds, and which were now precipitated over the entire face of Europe. Having for some time ceased to plead for toleration, and learnt to be aggressive, she not only stood the shock of change but girded herself for the difficult work of calming the agitated elements of society, of teaching the nations a higher faith than a savage form of nature worship, of purifying and refining their recklessness, independence, and uncontrollable love of liberty, and fitting them to become members of an enlightened Christendom.

(*a*) *The Celtic Missionaries.*—The first pioneers who went forth to engage in this difficult enterprise came from the secluded Celtic churches of Ireland and the Scottish Highlands, which, though almost forgotten amidst the desolating contest which was breaking up the Roman world, were no sooner founded than they sent forth "armies of Scots" to pour back upon the Continent the gifts of civilization and the gospel. Of many who deserve mention in connexion with this period, the most prominent were—Columba, the founder of the famous monastery of Iona, and the evangelizer of the Albanian Scots and northern Picts; Aidan, the apostle of Northumbria; Columbanus, the apostle of the Burgundians of the Vosges; Callich or Gallus, the evangelizer of north-eastern Switzerland and Alemannia; Kilian, the apostle of Thuringia; and Trudpert, the martyr of the Black Forest. The zeal of these singular men at the head of ardent disciples seemed to take the world by storm. Travelling generally in companies, and carrying a simple outfit, these Celtic pioneers flung themselves on the Continent of Europe, and, not content with reproducing at Annegray or Luxeuil the willow or brushwood huts, the chapel and the round tower, which they had left behind in Derry or in the island of Hy, they braved the dangers of the northern seas, and penetrated as far as the Faroes and even far distant Iceland.[3]

(*b*) *The English Missionaries.*—Thus they laid the foundations, awing the heathen tribes by their indomitable spirit of self-sacrifice and the sternness of their rule of life. But, marvellous as it was, their work lacked the element of permanence; and it became clear that if Europe was to be carried through the dissolution of the old society, and missionary operations consolidated, a more practical system must be devised and carried out. The men for this work were now ready. Restored to the commonwealth of nations by the labours of the followers of Augustine of Canterbury and the Celtic missionaries from Iona, the sons of the newly evangelized English churches were ready to go forth to the help of their Teutonic brothers in the German forests. The energy which warriors were accustomed to put forth in their efforts to conquer was now "exhibited in the enterprise of conversion and teaching"[4] by Wilfrid on the coast of Friesland,[5] by Willibrord in the neighbourhood of Utrecht,[6] by the martyr-brothers Ewald or Hewald amongst the "old" or continental Saxons,[7] by Swidbert the apostle of the tribes between the Ems and the Yssel, by Adelbert, a prince of the royal house of Northumbria, in the regions north of Holland, by Wursing, a native of Friesland, and one of the disciples of Willibrord, in the same region, and last, not least, by the famous Winfrid or Boniface, the "apostle of Germany," who went forth first to assist Willibrord at Utrecht, then to labour in Thuringia and Upper Hessia, then, with the aid of his kinsmen Wunibald and Willibald, their sister Walpurga, and her thirty companions, to consolidate the work of earlier missionaries, and finally to die a martyr on the shore of the Zuyder Zee.

(*c*) *Scandinavian Missions.*—Devoted, however, as were the labours of Boniface and his disciples, the battle was not yet nearly won. All that he and they and the emperor Charlemagne after them achieved for the fierce untutored world of the 8th century seemed to have been done in vain when, in the 9th, "on the north and north-west the pagan Scandinavians were hanging about every coast, and pouring in at every inlet; when on the east the pagan Hungarians were swarming like locusts and devastating Europe from the Baltic to the Alps; when on the south and south-east the Saracens were pressing on and on with their victorious hosts. It seemed then as if every pore of life were choked, and Christendom must be stifled and smothered in the fatal embrace."[8] But it was even now that one of the most intrepid of missionary enterprises was undertaken, and the devoted Anskar went forth and proved himself a true apostle of Denmark and Sweden, sought out the Scandinavian viking in his native home and icy fiords, and, after persevering in the face of apparently insurmountable difficulties and hardships, handed on the torch of self-denying zeal to others, who "casting their bread on the waters" saw, after the lapse of many years, the close of the monotonous tale of burning churches and pillaged monasteries, and taught the fierce Northman to lay aside his old habits of piracy, and gradually learn respect for civilized institutions.

(*d*) *Slavonic Missions.*—Thus the "gospel of the kingdom" was successively proclaimed to the Roman, the Celtic, the Teutonic, and the Scandinavian world. A contest still more stubborn remained with the Slavonic tribes, with their triple and many-headed divinities, their powers of good and powers of evil, who could be approached only with fear and horror, and propitiated only with human sacrifices. Mission work commenced in Bulgaria during the latter part of the 9th century; thence it extended to Moravia, where two Greek missionaries—Cyril and Methodius—provided for the people a Slavonic Bible

[1] Justin, *Dial.* c. 117; Tertull., *Apol.*, 37; Id., *Adv. Jud.*, 7.
[2] Theodoret, *H.E.*, v. 30.
[3] See A. W. Haddan, "Scots on the Continent," *Remains*, p. 256.
[4] Church, *Gifts of Civilization*, p. 330.
[5] Bede, *H.E.*, v. 19.
[6] "Annal. Xantenses," Pertz, *Mon. Germ.*, ii. 220.
[7] Bede, *H.E.*, v. 10.
[8] See Lightfoot, *Ancient and Modern Missions.*

and a Slavonic Liturgy; thence to Bohemia, and so onwards to the Scythian wilds and level steppes, where arose the Russian kingdom of Ruric the Northman, and where about the close of the 10th century the Eastern Church "silently and almost unconsciously bore into the world her mightiest offspring."[1] But, though the baptism of Vladimir and the flinging of the triple and many-headed idols into the waters of the Dnieper was a heavy blow to Slavonic idolatry, mission work was carried on with but partial success; and it taxed all the energies of Albrecht, bishop of Bremen, of Vicilin, bishop of Oldenburg, of Bishop Otto of Bamberg the apostle of the Pomeranians, of Adalbert the martyr-apostle of Prussia, to spread the word in that country, in Lithuania, and in the territory of the Wends. It was not till 1168 that the gigantic four-headed image of Swantevit was destroyed at Arçona, the capital of the island of Rügen, and this Mona of Slavonic superstition was included in the advancing circle of Christian civilization. As late as 1230 human sacrifices were still being offered up in Prussia and Lithuania, and, in spite of all the efforts of the Teutonic Knights to expel by force the last remains of heathenism from the face of Europe, idolatrous practices still lingered amongst the people, while in the districts inhabited by the Lapps, though successful missions had been inaugurated as early as 1335, Christianity cannot be said to have become the dominant religion till at least two centuries later.

(*e*) *Moslem Missions.*—The mention of the order of the Teutonic Knights reminds us how the crusading spirit had affected Christendom, and exchanged the patience of a Boniface or an Anskar for the fiery zeal of the warrior of the cross. Still it is refreshing to notice how even now there was found the famous Raymond Lully to protest against propagandism by the sword, to urge on pope after pope the necessity of missions amongst the Moslems, and to seal his testimony with his blood outside the gates of Bugiah in northern Africa (June 30, 1315). Out of the crusades, however, arose other efforts to bear the banner of the cross into the lands of the East, and to develop the work which Nestorian missionaries from Baghdad, Edessa, and Nisibis had already inaugurated along the Malabar coast, in the island of Ceylon, and in the neighbourhood of the Caspian Sea. In 1245 the Roman pontiff sent two embassies, one to charge the Mongol warriors to desist from their desolating inroads into Europe, the other to attempt to win them over to the Christian faith. The first, a party of four Dominicans, sought the commander-in-chief of the Mongol forces in Persia; the second, consisting of Franciscans, made their way into Tartary, and sought to convert the successor of Oktai-Khan. Their exertions were seconded in 1253 by the labours of another Franciscan whom Louis IX. of France sent forth from Cyprus,[2] while in 1274 the celebrated traveller Marco Polo, accompanied by two learned Dominicans, visited the court of Kublai-Khan, and at the commencement of the 14th century two Franciscans penetrated as far as Peking, and kept alive a flickering spark of Christianity in the Tartar kingdom, even translating the New Testament and the Psalter into the Tartar language, and training youths for a native ministry.[3]

(*f*) *Missions to India and the New World.*—These tentative missions in the East were now to be supplemented by others on a larger scale. In 1486 the Cape of Good Hope was rounded by Dias, and in 1508 the foundations of the Portuguese Indian empire were laid by Albuquerque. Columbus also in 1492 had landed on San Salvador, and the voyages of the Venetian Cabot along the coast of North America opened up a new world to missionary enterprise. These bold discoverers had secured the countenance of the pope on the condition that wherever they might plant a flag they should be also zealous in promoting the extension of the Christian faith. Thus a grand opportunity was given to the churches of Portugal and Spain. But the zeal of the Portuguese, even when not choked by the rising lust of wealth and territorial power, took too often a one-sided direction, repressing the Syrian Christians on the Malabar coast, and interfering with the Abyssinian Church,[4] while the fanatic temper of the Spaniard, maddened by his prolonged conflict with the infidel at home, betrayed him into methods of propagating his faith which we cannot contemplate without a shudder, consigning, in Mexico and Peru, multitudes who would not renounce their heathen errors to indiscriminate massacre or abject slavery.[5] Their only defender for many years was the famous Las Casas, who, having sojourned amongst them till 1516, has drawn a terrible picture of the oppression he strove in vain to prevent.[6] Some steps indeed were taken for disseminating Christian principles, and the pope in granting territory to the crowns of Spain and Portugal had specially urged this duty, and had been instrumental in inducing a band of missionaries, chiefly of the mendicant orders, to go forth to this new mission field.[7] But the results were scanty. Only five bishoprics had been established by 1520, and the number of genuine converts was small. In settling, however, his realm the conqueror of Mexico evinced no little solicitude for the spiritual welfare of his charge; and the labours of the devoted men whom he begged the emperor to send out were successful in banishing every vestige of the Aztec worship from the Spanish settlements.[8]

(*g*) *The Jesuit Missions.*—It was during the period at which we have now arrived that the great organization of the Jesuits came into existence, and one of the first of Loyola's associates, Francis Xavier, was also one of the greatest and most zealous missionaries of his or any other era. Encouraged by the joint co-operation of the pope and of John III. of Portugal, and strongly tinged like Loyola with ideas of chivalry and self-devotion, he disembarked at Goa on the 6th of May 1542, and before his death on the Isle of St John (Hiang-Shang), December 2, 1552, he had roused the European Christians of Goa to a new life, laboured with singular success amongst the Paravars, a fisher caste near Cape Comorin, gathered many converts in the kingdom of Travancore, visited the island of Malacca, made his way to and founded a mission in Japan, thence revisited Goa, and impelled by the quenchless desire to unfurl the banner of the cross in China, had set out thither to fall a victim to malignant fever at the early age of forty-six, within sight of that vast empire whose conversion had been the object of his holy ambition.

The immediate successor of Xavier, Antonio Criminalis, was regarded by the Jesuits as the first martyr of their society (1562). Mattheo Ricci, an Italian by birth, was also an indefatigable missionary in China for twenty-seven years, while the peculiar methods of unholy compromise with Brahmanism in India followed by Robert de' Nobili drew down the condemnatory briefs of pope after pope, and were fatal to the vitality of his own and other missions.

[1] Stanley, *Eastern Church*, p. 294.
[2] Neander, vii. 69; Hakluyt, 171; Huc, i. 207.
[3] Neander, vii. 79; Gieseler, iv. 259, 260; Hardwick, *Middle Ages*, 235–337.
[4] Geddes, *History of the Church of Malabar*, p. 4; Neale, *Eastern Church*, ii. 343.
[5] Prescott, *Conquest of Mexico*, i. 318, iii. 218.
[6] *Relacion de la Destruycion de las Indias.*
[7] Prescott, *Mexico*, iii. 218 n.
[8] Prescott, iii. 219.

Other representatives of the same order worked with success in evangelizing the Spanish settlement of Paraguay in 1582, while their defeated foes the Huguenots sent forth under a French knight of Malta a body of devoted men to attempt the formation of a Christian colony at Rio Janeiro. By the close of the 16th century the unflagging zeal of the Jesuits led to a more complete development and organization of the missionary system of the Roman Church. To give unity and solidity to the work of missions, a committee of cardinals was appointed under the name of the "Congregatio de propaganda fide," and to it was entrusted the entire management of the mission, conducted under the superintendence of the pope. The scheme originated with Gregory XIII., but was not fully organized till forty years afterwards, when Gregory XV. gave it plenary authority by a bull dated June 2, 1622. Gregory's successor, Urban VIII., supplemented the establishment of the congregation by founding in connexion with it a great missionary college, where Europeans might be trained for foreign labours, and natives might be educated to undertake mission work wherever new colonies were settled. At this college is the missionary printing-press of the Roman Church, and its library contains an unrivalled collection of literary treasures bearing on the particular work. From its walls have gone forth numbers of devoted men, who have proved themselves able to promote in a singular degree the enlargement of the boundaries of the church by means of material as well as spiritual forces.

3. *The Modern Period.*

This last period of missionary activity is distinguished in a special degree by the exertions of societies for the development of mission work.

As contrasted with the colossal display of power on the part of the Church of Rome, it must be allowed that the churches which in the 16th century broke off from their allegiance to the Latin centre at first presented a great lack of anxiety for the extension of the gospel and the salvation of the heathen. The causes of this, however, are not far to seek. The isolation of the Teutonic churches from the vast system with which they had been bound up, the conflicts and troubles among themselves, the necessity of fixing their own principles and defining their own rights, concentrated their attention upon themselves and their own home work, to the neglect of work abroad.

Still the development of the maritime power of England, which the Portuguese and Spanish monarchies noted with fear and jealousy, was distinguished by a singular anxiety for the spread of the Christian faith. Edward VI. in his instructions to the navigators in Willoughby's fleet, Cabot in those for the direction of the intended voyage to Cathay, good old Hakluyt, who promoted many voyages of discovery in addition to writing their history, agree with Sir Humphrey Gilbert's chronicler that "the sowing of Christianity must be the chief intent of such as shall make any attempt at foreign discovery, or else whatever is builded upon other foundation shall never obtain happy success or continuance." When on the last day of the year 1600 Queen Elizabeth granted a charter to George, earl of Cumberland, and other "adventurers," to be a body-corporate by the name of "The Governor and Company of Merchants of London trading with the East Indies," the expressed recognition of higher duties than those of commerce may by some be deemed a mere matter of form, and, to use the words of Bacon, "what was first in God's providence was but second in man's appetite and intention." Yet a keen sense of missionary duty marks many of the chronicles of English mariners. Notably was this the case with the establishment of the first English colony in America, that of Virginia, by Sir Walter Raleigh. The philosopher Heriot, one of his colleagues, laboured for the conversion of the natives, amongst whom the first baptism is recorded to have taken place on August 13, 1587.[1] Raleigh himself presented as a parting gift to the Virginian Company the sum of £100 "for the propagation of the Christian religion" in that settlement.[2] When James I. granted letters patent for the occupation of Virginia it was directed that the "word and service of God be preached, planted, and used as well in the said colonies as also as much as might be among the savages bordering among them"; and the honoured names of Nicolas Ferrar, John Ferrar, Dr Donne, and Sir John Sandys, a pupil of Hooker, are all found on the council by which the home management of the colony was conducted.

In the year 1618 was published *The True Honour of Navigation and Navigators*, by John Wood, D.D., dedicated to Sir Thomas Smith, governor to the East India Company, and much about the same time appeared the well-known treatise of the famous Grotius, *De Veritate Religionis Christianæ*, written for the express use of settlers in distant lands. The wants, moreover, of the North American colonies did not escape the attention of Archbishop Laud during his official connexion with them as bishop of London, and he was developing a plan for promoting a local episcopate there when his troubles began and his scheme was interrupted. During the Protectorate, in 1649, an ordinance was passed for "the promoting and propagating of the gospel of Jesus Christ in New England" by the erection of a corporation, to be called by the name of the President and Society for the Propagation of the Gospel in New England, to receive and dispose of moneys for the purpose, and a general collection was ordered to be made in all the parishes of England and Wales; and Cromwell himself desired a scheme for setting up a council for the Protestant religion, which should rival the Roman Propaganda, and consist of seven councillors and four secretaries for different provinces.[3] On the restoration of the monarchy, through the influence of Richard Baxter with Lord Chancellor Hyde, the charter already granted by Cromwell was renewed, and its powers were enlarged. For now the corporation was styled "The Propagation of the Gospel in New England and the parts adjacent in America," and its object was defined to be "not only to seek the outward welfare and prosperity of those colonies, but more especially to endeavour the good and salvation of their immortal souls, and the publishing the most glorious gospel of Christ among them." On the list of the corporation the first name is the earl of Clarendon, while the Hon. Robert Boyle was appointed president. Amongst the most eminent of its missionaries was the celebrated John Eliot, who, encouraged by Boyle, and assisted by him with considerable sums of money, brought out the Bible in the Indian language in 1661–64, having revealed at the end of the Indian grammar which he had composed the secret of his success: "prayer and pains, through faith in Jesus Christ, will do anything." Boyle displayed in other ways his zeal for the cause of missions. He contributed to the expense of printing and publishing at Oxford the four Gospels and the Acts of the Apostles in the Malay language, and at his death left £5400 for the propagation of the gospel in heathen lands.

The needs of the colonial church soon excited the attention of others also, and great efforts were made by Bishop Beveridge, Archbishop Wake, Archbishop Sharpe, Bishop Gibson, and afterwards by the philosophic Bishop Berkeley, and Bishop Butler, the famous author of the *Analogy*, to

[1] Hakluyt, *Voyages*, iii. 345.
[2] Oldy, *Life of Raleigh*, p. 118.
[3] Neale, *History of New England*, i. p. 260; Burnet, *History of his own Times*, i. p. 132.

develop the colonial church and provide for the wants of the Indian tribes. In 1696 Dr Bray, at the request of the governor and assembly of Maryland, was selected by the bishop of London as ecclesiastical commissary; and, having sold his effects, and raised money on credit, he sailed for Maryland in 1699, where he promoted, in various ways, the interests of the church. Returning to England in 1700–1, and supported by all the weight of Archbishop Tenison and Bishop Compton, he was graciously received by William III., and received letters patent under the great seal of England for creating a corporation by the name of the "Society for the Propagation of the Gospel in Foreign Parts" on the 16th of June 1701.

With the establishment of this corporation the era of the activity of societies for carrying out mission work may be said to commence, though the opening of the 18th century saw other movements set on foot for the same object. Thus in 1705 Frederick IV. of Denmark founded a mission on the Coromandel coast, and inaugurated the labours of Ziegenbalg, Schultze, and Schwartz, whose devotion and success told with such remarkable reflex influence on the church at home. Again in 1731 the Moravians illustrated in a signal degree the growing consciousness of obligation towards the heathen. Driven by persecution from Moravia, hunted into mountain-caves and forests, they had scarcely secured a place of refuge in Saxony before, "though a mere handful in numbers, yet with the spirit of men banded for daring and righteous deeds, they formed the heroic design, and vowed the execution of it before God, of bearing the gospel to the savage and perishing tribes of Greenland and the West Indies, of whose condition report had brought a mournful rumour to their ears." And so, literally with "neither bread nor scrip," they went forth on their pilgrimage, and, incredible as it sounds, within ten years they had established missions in the islands of the West Indies, in South America, Surinam, Greenland, among the North American tribes, in Lapland, Tartary, Algiers, Guinea, the Cape of Good Hope, and Ceylon.[1]

Such were the preparations for the more general movements during the last hundred years, and the manifestation of missionary zeal on a scale to which it would be difficult to find a parallel in Western Christianity.

The progress that has been made may be best judged of from consideration of the following details:—

(*a*) At the close of the last century there were only seven missionary societies in existence, properly so called. Of these three only, the Society for the Propagation of the Gospel in Foreign Parts, the Halle-Danish Society, and the Moravians, had been at work for the greater part of the century, whilst four, the Church Missionary Society, the Baptist Missionary Society, the London Missionary Society, and the Dutch Society at Rotterdam, began their work only in its tenth decade. To-day these seven have, in Europe and America alone, increased to upwards of seventy, and to these must be added, not only several independent societies in the colonies, but numerous missionary associations on a smaller scale, the offspring of English and American societies.

(*b*) The following chronological lists illustrate the growth of missionary societies in Britain and the United States:—

Great Britain and Ireland.

1691. Christian Faith Society for the West Indies.
1698. *Society for Promoting Christian Knowledge.*
1701. Society for the Propagation of the Gospel in Foreign Parts.
1732. Moravian (Episcopal) Missions of the United Brethren.
1792. Baptist Missionary Society.
1795. London Missionary Society.
1796. *Scottish Missionary Society.*
1799. Church Missionary Society.
1799. Religious Tract Society.
1804. British and Foreign Bible Society.
1808. London Society for Promoting Christianity among the Jews.
1813. *Wesleyan Missionary Society.*
1817. General Baptist Missionary Society.
1823. *Colonial and Continental Church Society.*
1829. Church of Scotland Mission Boards.
National Bible Society of Scotland.
1831. Trinitarian Bible Society.
1832. Wesleyan Ladies' Auxiliary for Female Education in Foreign Countries.
1834. Society for Promoting Female Education in the East.
1835. United Secession (now United Presbyterian) Foreign Missions.
1836. Colonial Missionary Society.
1840. Foreign Aid Society.
Coral Missionary Fund.
1840. Welsh Calvinistic Methodist Missionary Society.
1841. Colonial Bishoprics Fund.
1841. Edinburgh Medical Missionary Society.
Waldensian Missions Aid Fund.
1843. British Society for the Propagation of the Gospel among the Jews.
1843. Free Church of Scotland Missions.
1843. Primitive Methodist African and Colonial Missions.
Methodist New Connexion in England Foreign Missions.
1844. South American Missionary Society.
1849. Evangelical Continental Society.
1852. Indian Female Normal School Society.
1853. Lebanon Schools.
1855. Presbyterian Church in England Foreign Missions.
1856. Turkish Missions Aid Society.
1856. United Methodist Free Churches Foreign Missions.
1858. Christian Vernacular Education Society for India.
1860. Central African Mission of the English Universities.
1860. British Syrian Schools.
Melanesian Mission.
1865. Ladies' Association for Promoting Female Education among the Heathen.
1866. China Inland Mission.
1867. *Delhi Female Medical Mission.*
1867. "Friends" Foreign Mission Association.
1868. Cape Town Aid Association.
1869. "Friends" Mission in Syria and Palestine.
Irish Presbyterian Missions.
1876. *Spanish and Portuguese Church Aid Society.*
Columbia Mission.
Original Secession Church Indian Mission.
1877. Cambridge Mission to Delhi.
1880. Church of England Zenana Missionary Society.

United States of America.

1733. Corporation for the Propagation of the Gospel in New England.
1787. Society for Propagating the Gospel among the Indians at Boston.
1800. New York Missionary Society.
Connecticut Missionary Society for Indians.
1803. United States Mission to the Cherokees.
1806. Western Missionary Society for Indians.
1810. Board of Commissioners for Foreign Missions.
1814. Baptist Missionary Union.
1819. Methodist Episcopal Church Missionary Society.
1833. Free-will Baptist Foreign Missionary Society in India.
1835. Foreign Missions of the Protestant Episcopal Church.
1837. Board of Foreign Missions of the Presbyterian Church.
1837. Evangelical Lutheran Foreign Missionary Society.
1842. Seventh Day Baptist Missionary Society
Strict Baptist Missionary Society.
1843. Baptist Free Missionary Society.
1845. Methodist Episcopal Church, South.
1845. Southern Baptist Convention.
1846. American Missionary Association.
1857. Board of Foreign Missions of (Dutch) Reformed Church.
1859. Board of Foreign Missions of United Presbyterian Church.
American United Brethren, Moravian.
United States German Evangelical Missionary Society.
American Mexican Association.
Indian Home Missionary Association.
Indian Missionary Association.
Local Baptist Missionary Society.
Women's Union Zenana Missionary Society.

(*c*) At the beginning of the present century the total sum contributed for Protestant missions can hardly be said to have amounted to £50,000; in 1882 the amount raised by British contributions alone to foreign missions amounted to upwards of £1,090,000,[2] thus divided:—

Church of England Missions	£460,935
Joint Societies of Churchmen and Nonconformists	153,320
Nonconformist Societies, English and Welsh	313,177
Scottish and Irish Societies	155,767
Roman Catholic Societies	10,910

(*d*) At the same date it is calculated that there were about 5000 heathen converts under instruction, not counting those belonging to the Roman Catholic missions. At the present day the converts from heathenism may be estimated certainly at no less than 1,800,000, a single year (1878) showing an increase of about 60,000.

(*e*) When the Society for the Propagation of the Gospel was founded in 1701, there were probably not twenty clergymen of the Church of England in foreign parts. The spiritual condition of the settlers in America and elsewhere was terrible in the extreme, and no effort was then made by the church to win over the heathen to Christ. But now the position which the church holds in the British colonies and dependencies and many parts of heathendom is recognized by all. In those regions where the society labours, and which before it commenced its work were spiritually the "waste places" of the earth, there are, including the American Church (*the first fruits of the society's efforts*), 138 bishops, more than 5000 clergy, and upwards of 2,000,000 members of the communion.

The above tables sufficiently indicate how varied are the missionary agencies now at work, covering the heathen

[1] Holmes, *Hist. Sketches of the Missions of the United Brethren*, p. 3; Grant, *Bampton Lectures*, p. 190.

[2] See Scott Robertson, *Analysis of British Contributions to Foreign Missions*, 1883.

world with a network of mission outposts, which within the last century have won nearly two millions of converts to the Christian faith.

The continuity of missionary enthusiasm maintained through the primitive, the mediæval, and the modern periods of the church's history, operating at every critical epoch, and surviving after periods of stagnation and depression, is a very significant fact. It is true that other religions have been called missionary religions, and that one of them occupies the first place in the religious census of mankind.[1] But the missionary activity of Buddhism is a thing of the past, and no characteristic rite distinguishing it has found its way into a second continent; while, as for Mohammedanism, the character of its teaching is too exact a reflexion of the race, time, place, and climate in which it arose to admit of its becoming universal.[2] These and other religions of the far East may still maintain their hold over millions, but it must be admitted that their prospect of endurance in the presence of advancing Christianity is very small, and it is difficult to trace the slightest probability of their harmonizing with the intellectual, social, and moral progress of the modern world. With all its deficiencies, the Christian church has gained the "nations of the future," and whereas in the 3d century the proportion of Christians to the whole human race was only that of one in a hundred and fifty, this has now been exchanged for one in five,[3] and it is indisputable that the progress of the human race at this moment is entirely identified with the spread of the influence of the nations of Christendom.

Side by side with this continuity of missionary zeal, a noticeable feature is the immense influence of individual energy and the subduing force of personal character. Around individuals penetrated with Christian zeal and self-denial has centred not merely the life, but the very existence, of primitive, mediæval, and modern missions. What Ulfila was to the Gothic tribes, what Columba and his disciples were to the early Celtic missions, what Augustine or Aidan was to the British Isles, what Boniface was to the churches of Germany and Anskar to those of Denmark and Sweden, that, on the discovery of a new world of missionary enterprise, was Xavier to India, Hans Egede to Greenland, Eliot to the Red Indians, Martyn to the church of Cawnpore, Marsden to the Maoris, Carey and Marshman to Burmah, Heber, Wilson, Milman, and Duff to India, Gray, Livingstone, Mackenzie, Steere, Callaway to Africa, Broughton to Australia, Patteson to Melanesia, Mountain and Feild to Newfoundland, Crowther to the Niger Territory, Brett to Guiana. At the most critical epochs such men have ever been raised up, and the reflex influence of their lives and self-denial has told upon the church at home, while apart from their influence the entire history of important portions of the world's surface would have been altered.

If from the agents themselves we turn to the work that has been accomplished it will not be disputed that the success of missions has been marked amongst rude and aboriginal tribes. What was true in the early missions has been found true in these latter times. The rude and barbarous northern peoples seemed to fall like "full ripe fruit before the first breath of the gospel." The Goths and the Vandals who poured down upon the Roman empire were evangelized so silently and rapidly that only a fact here and there relating to their conversion has been preserved. Now this is exactly analogous to modern experience in the South Seas, America, and Africa. We must here content ourselves with a cursory survey of what missionary enterprise has accomplished in those regions and among the more civilized nations of Eastern Asia.

[1] Max Müller, *Chips*, iv. p. 265.
[2] Newman, *Grammar of Assent*, p. 424.
[3] Lightfoot, *Comparative Progress of Ancient and Modern Missions*, p. 8.

The South Seas.—That missions have done much in these regions in suppressing cannibalism, human sacrifices, and infanticide, humanizing the laws of war, and elevating the social condition of women, is a fact confirmed by the researches of Meinicke, Waitz, Gerland, Oberlander, and even of Darwin.[4]

In Australia work among the aborigines, wherever it has been zealously conducted, has been blessed with signal success. Amongst the Papuans the Moravian stations of Ebenezer in the district of Wimmera, and Ramahyuck in that of Gippsland, can point to their little villages of 125 native Christian inhabitants, their cleanly houses, and their well-ordered churches. In the district of South Adelaide, at Point Macleay, the Scottish Presbyterian Mission has been similarly successful, while in New Zealand the native population was converted almost within a single generation. In the islands north and north-west of Australia the Dutch missionaries have been especially successful in the Minahassa (see CELEBES), of whose 114,000 inhabitants more than 80,000 have been won over to the Christian faith, forming 195 communities with 125 schools; and in southern Borneo, the Rhenish Mission in the south and the Society for the Propagation of the Gospel in the north have been enabled to establish themselves firmly, while the former society has also done a great work among the Battaks in Sumatra. Amongst the dark-coloured races of Polynesia missionary work has made great advances through the labours of the London Missionary Society, the Wesleyans, and the American Board. Making Tahiti its basis of operations, the first-named society has carried on missionary operations in the islands of Australasia, Hervey, Samoa, Tokelau, and Ellice, while the American Board has witnessed equally favourable results in the Sandwich Islands, and in Micronesia (Caroline, Marshall, and Gilbert Islands) the agents of the Hawaiian Association are actively at work under the direction of American missionaries. In Melanesia the Society for the Propagation of the Gospel, the Wesleyans, the London Missionary Society, and the Presbyterians are all actively engaged. The Fiji group stands out as one of the most promising centres of Christian civilization, and the governor, Sir A. Gordon, was enabled to report in 1879 that, out of a population of about 120,000, 102,000 are now regular worshippers in the churches, which number 800, while over 42,000 children are in attendance in 1534 Christian day schools. The Loyalty Islands have been occupied partly by Roman Catholic missions and partly by the London Missionary Society, while in the New Hebrides the missionaries of the Free Church of Scotland and of the Presbyterian churches of Canada, New Zealand, and Australia, in spite of many obstacles, the unhealthiness of the climate, and the variety of the dialects spoken, have upwards of 3000 natives receiving Christian teaching, 800 communicants, and 100 native teachers. On the islands of Banks, Santa Cruz, and Solomon, the English Episcopal Church is achieving no little success, sending native youths for months at a time to Norfolk Island to receive instruction, whence they return again in order to spread the knowledge of truth at home. These islands will ever be famous in connexion with the martyr death of the noble Bishop Patteson.

The Uncivilized Peoples of America.—The quiet humble labours of the Moravians have accomplished much in Greenland and Labrador, whilst among the Indians of Canada and the people of Hudson's Bay the Society for the Propagation of the Gospel has not laboured in vain, nor the Church Missionary Society in the dioceses of Rupertsland, Red River, Saskatchewan, and Moosonee. At Columbia, on the coast of the Pacific, a practical missionary genius named William Duncan has succeeded in civilizing a body of Indians degraded by cannibalism, and at his Metlakahtla mission stands at the head of a community of some thousand persons, which has a larger church than is to be found between there and San Francisco. Testimony to the value of the results achieved was borne in 1876 by Lord Dufferin, then governor-general of Canada, who declared that he could hardly find words to express his astonishment at what he witnessed. Amongst the Indian tribes of the United States work is carried on by the Moravians, the American Board of Missions, the Presbyterians of the North and South, the Baptists, the Episcopal Methodists, and the American Missionary Society; and the result is that 27,000 Indians, divided amongst the 171 communities of different denominations (including the Roman Catholic) are in full membership with the church, and have 219 places of worship, besides 366 schools attended by about 12,222 Indian children. The Cherokees, the Choctaws, the Creeks, the Chickasaws, have their own churches, schools, and academies, and may compare favourably both intellectually and morally with their white neighbours in Missouri, Arkansas, and Texas.[5] Amongst the negroes in the United States more than 1000 places of worship have been built since the last war, while the American Missionary Association alone has erected 26 academies with about 6000 students, for the purpose of

[4] See Christlieb, *Foreign Missions*, p. 88. [5] *Ibid.*, pp. 98, 99.

preparing freed slaves to be teachers and missionaries. Amongst the Indians on the Essequibo and Berbice in British Guiana, the missions of the Society for the Propagation of the Gospel have been rapidly extended, and now upwards of half the Indian population are members of Christian churches. In the British West Indies, through the united labours of various missionary societies, out of 1,000,000 inhabitants upwards of 248,000 are returned as regular members of the churches, 85,000 as communicants, while 78,600 children receive instruction in 1123 day schools, of which number about 45,000 belong to Jamaica.

Passing to the southern promontory of South America, we find that the self-denying labours of Allen Gardiner are beginning to justify the devotion that prompted them. The London South American Missionary Society not only carries on its operations in the Falkland Islands, where youths from Tierra del Fuego receive instruction, but has founded stations in Tierra del Fuego itself, has roused the natives of Patagonia from their spiritual deadness, and has extended its labours even to the Indians in Brazil.

Africa.—Here there are three great regions of missionary activity,—on the west coast, in the south, and in some parts of the east.

The largest and most fruitful mission field in West Africa is that of Sierra Leone, where at least seven-eighths of the people are now Christians, though the first mission does not date further back than the present century;[1] and important results have also been obtained in Senegambia (on the Pongas), in Old Calabar, and in the republic of Liberia. On the Gold and Slave Coasts the labours of English Wesleyan missionaries and of the North German missionary societies have been crowned with no small success, while the Basel Society, which celebrated its jubilee in 1878, has extended its sphere of activity to Ashantee, translating the Scriptures into the native languages, and changing primeval marshes into bright-looking Christian villages. In the Yoruba lands the Church Missionary Society has 11 stations, 5994 Christians, and 1657 scholars, while on the Niger we are confronted with the interesting spectacle of negro preachers and teachers labouring under the coloured Bishop Crowther, carrying on a work which within the last few years was consecrated by the blood of martyrs.

South Africa has for some time been a centre of missionary activity. Here thirteen British and Continental associations have proved that all the South African races, Hottentots and Kaffres, Fingoes and Bechuanas, Basutos and Zulus, are capable of attaining a considerable degree of Christian civilization, and can not only be instructed in handicraft and agriculture, but trained as ministers and teachers. A single instance of this is afforded in British Kaffraria by the Lovedale Institute of the Free Church of Scotland, where youths from all the above-mentioned tribes are taught along with Europeans, and every Sunday sixty students proclaim the gospel in the neighbouring villages. In the cause of mission work here few ever laboured more zealously than the late Bishop Gray, whose diocese, when first constituted, included the whole colony of the Cape, but whose successor has now for his suffragans the bishops of Grahamstown, Maritzburg, St Helena, Bloemfontein, Zululand, St John's, and Pretoria.

East and East Central Africa, so long neglected, is now being rapidly occupied by missionary enterprise. Here the island of Madagascar has been in great part evangelized, while on the island of Mauritius the Anglican Mission has developed pre-eminent results. On the mainland, the coast of Zanzibar calls for special notice. Here the little island of the same name has long been the seat of the Universities Mission to Central Africa, and the heroic Bishop Steere has not only erected a cathedral on the site of the former slave-market, but translated the New Testament into Sawahili, a language which can be understood by the tribes around the lakes, and even in Uganda.

China.—"O mighty fortress! when shall these impenetrable brazen gates of thine be broken through?" was the mournful exclamation of Valignani, the successor of Xavier, as he gazed in sadness at the mountains of China. The words well express the incredible difficulties which this largest and most thickly peopled heathen land in the world, with its petrified constitution and culture of three thousand years, presents in the way of missionary effort. The country itself, the people, their speech, their manners, their religion, their policy, seemed to unite in opposing an insuperable barrier, but history has to record how efforts have been made by many bodies, and at many times, to break it down. An early Nestorian Church established itself in the empire, but was either uprooted, or died out in course of time. In the 16th century the Jesuits undertook the task, and in spite of the persecutions which they have undergone the missions of the Roman Church, with their numerous foreign clergy and their hosts of natives of different ecclesiastical degrees, have attained no small measure of success. Before the country was really opened to foreigners by the treaty of Tientsin, pioneers proceeded thither from America, and from the London Missionary Society. The labours of Dr Legge in translating and reducing to system the Chinese classics are well known. At the present day it is estimated that there are upwards of 29 societies at work in the country, with about 250 ordained missionaries and 63 female teachers, and the number is constantly increasing. These societies, of which the largest proportion belong to England, and the next largest to America, support, it is estimated, 20 theological schools, 30 higher boarding schools for boys with 611 scholars, 38 for girls with 777 scholars, 177 day schools for boys with 4000 to 5000 pupils in attendance, 82 for girls with 1307, while 16 missionary hospitals and 24 dispensaries are under the direction of medical missionaries, whose work in China has been recognized almost from the first as the source of the greatest blessing. The mission centres stud the east coast from Hong Kong and Canton to the frontiers of Manchuria in the north; thence they advance little by little every year into the interior, while as yet the western provinces are scarcely touched by missionary effort. The literary labours of the various societies have been carried on with the utmost perseverance; and on the foundations laid by a Morrison and a Milne later toilers have been enabled to raise a superstructure of translations of various portions of the Bible, as well as various Christian books and religious and general periodicals which constitute a means of vast importance towards gradually gaining over this land of culture. At Peking a Russian mission has been labouring for more than one hundred and fifty years. The Society for the Propagation of the Gospel and the Church Missionary Society have lately opened up new centres in this almost limitless country.[2]

Japan.—Of the missions in Japan it is as yet too early to forecast the future. The signing of the commercial treaties of 1854 and 1858 with America and England was followed in 1859 by efforts on the part of the American churches to extend a knowledge of Christianity, and in these Bishop Williams, an accomplished Japanese scholar, proved himself a valuable leader and guide. Soon afterwards other societies found their way into the country, and in March 1872 the first Japanese congregation, of 11 converts, was constituted in Yokohama. Within the last eight years these 11 have increased to 1200, while the American missions have been supplemented by those of the Church Missionary Society and the Society for the Propagation of the Gospel. Nearly every mission has what may be called a high school for girls, and these institutions are very popular. Thousands of copies also of the Gospels have been circulated in Japanese, and representatives of nearly all the missions are engaged in translating the entire New Testament, while a Russo-Greek mission has established itself in the north, and is advancing steadily, having already made about 3000 converts.[3] Thus, when it is considered that in the beginning of the 17th century the Japanese Government drove out the Portuguese and massacred the native Catholic converts, and prohibited all Christians under pain of death from ever setting foot in the country, and when it is borne in mind that many of these old laws against Christianity have not yet been repealed and that the old distrust of strangers is still plainly discernible among the governing classes, it is clear that, while there is much ground for hope, effectual results can only be the work of time.

India.—What is true of China and Japan applies with tenfold force to India. Here the results achieved resemble those which were attained in the conflict between Christianity and the religion of old pagan Rome, with its mass of time-honoured customs interwoven with the literature, institutions, and history of the empire. Against the influence of prestige and settled prejudice the wave of the gospel beat for centuries in vain. Slowly and gradually it was undermining the fabric, but no striking results were immediately visible. So also in India with the Hindu proper Christianity has hitherto made inappreciable progress, while among the rude aboriginal or non-Aryan tribes its success has been remarkable. Independently of Roman Catholic missions upwards of twenty-eight societies are earnestly engaged in the English mission field, and the following figures will give some idea of the progress that has been made during the last twenty or thirty years. In British India, including Burmah and Ceylon, it is estimated that in 1852 there were 22,400 communicants and 128,000 native Christians young and old; in 1862 these had increased to 49,681 communicants and 213,182 native Christians; in 1872 there had been a further increase to 78,494 communicants and 318,363 native Christians, while in 1878 the latter figures rose to 460,000. When we look at the share that each of the societies has had in this increase, we find that the Society for the Propagation of the Gospel and the Church Missionary Society together have since 1850 increased in membership from 61,442 to upwards of 164,000; the London Missionary Society from 20,000 to upwards of 48,000; the Presbyterian missions of Scotland, England, Ireland, and America from 800 to 10,000; the Basel mission in India from 1000 to 6805; the Baptist missionary societies (including the American as well as the English) from 30,000 to 90,000; the five Lutheran societies from 3316 to about 42,000. In some places the progress made has been excep-

[1] See Lightfoot, *Ancient and Modern Missions*, p. 10.

[2] The Roman Catholic Mission had 404,530 converts in China in 1876, with a yearly increase of about 2000.

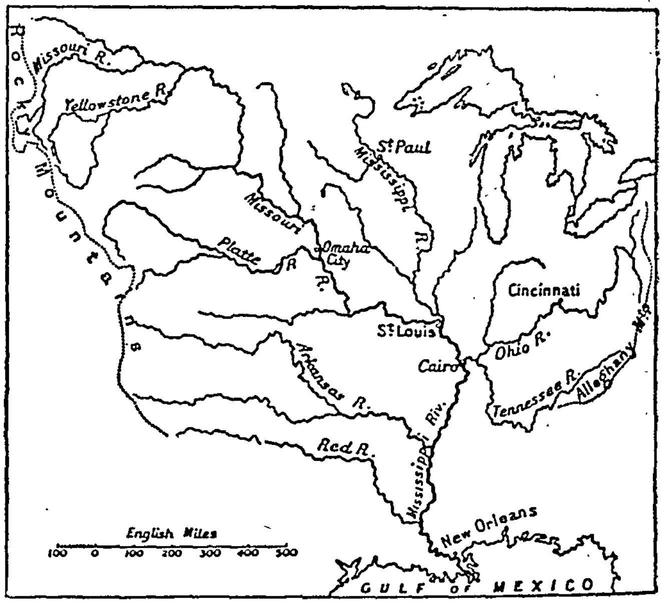
[3] Christlieb, *Foreign Missions*, p. 222.

tionally rapid. In Cuddapah, *e.g.*, in the Telugu territory, the Society for the Propagation of the Gospel and the London Missionary Society laboured side by side for upwards of thirty years without winning over more than 200 converts. Then on a sudden there sprang up a revival among the non-caste population, and the 200 became nearly 11,000. Among the Kols, after five years' waiting, the Gossner missionaries baptized their first converts in 1850; now in the German and English stations together these amount to about 40,000. Since the famine, however, in 1878–79, the increase of new converts has been still more rapid, and the practical experience of the superiority of Christian pity to heathen selfishness and of the helplessness of their heathen deities, united with the effect produced by persistent missionary labour in past years, brought thousands into the fold of the church. Thus in the Tinnevelly district, where the Church Missionary Society carries on its operations, upwards of 11,000 heathens applied in 1878 to Bishop Sargent and his native clergy for instruction preparatory to baptism.[1] In the same district, in connexion with the Society for the Propagation of the Gospel, between July 1877 and the end of June 1878 upwards of 23,564 persons betook themselves to Bishop Caldwell and his fellow-labourers for Christian teaching. Thus the English Church missions in Tinnevelly and Ramnad received in little more than a year and a half an increase of 35,000 souls,[2] and the Propagation Society is now proclaiming the gospel in nearly six hundred and fifty villages in the Tinnevelly district, amongst not merely food-seeking "rice Christians" but those who have had the courage to face severe persecution for joining the Christian church. Encouraging progress has also been made among the Santals and the Karens in Burmah and Pegu. Speaking generally, it may be said that the largest proportion of native converts is in the south, in the presidency of Madras; next to southern India the most fruitful field is Burmah, where the American Baptist missions are carrying on a successful work among the Karens, while the Propagation Society has founded many schools on the Irawadi, and penetrated up to Rangoon, and beyond British territory to Mandalay; next in point of numbers stand Bengal and the North-West Provinces. Here the largest contingent is supplied by the missions in Chutiá Nagpúr, among the aboriginal tribes of the Kols, while the Santal mission also presents many promising features. For the Punjab district and that of Sind, the Church Missionary Society has planted in Lahore a flourishing theological seminary for Christian Hindus, Sikhs, and Mohammedans, and Christianity has advanced thence by way of Peshawar into Afghanistan and Kashmir. It thus appears that by far the greatest measure of success has been obtained amongst the aboriginal races and those who are either of low caste or of no caste at all, while the real strongholds of the Hindu religion and civilization still stand out like strong fortresses and defy the attempts of the besiegers. Still the disintegrating agency of contact with Christianity is working out its slow but sure results. "Statistical facts," writes Sir Bartle Frere, "can in no way convey any adequate idea of the work done in any part of India. The effect is often enormous where there has not been a single avowed conversion. The teaching of Christianity amongst 160 millions of civilized industrious Hindus and Mohammedans in India is effecting changes, moral, social, and political, which for extent and rapidity in effect are far more extraordinary than any that have been witnessed in modern Europe." "The number of actual converts to Christianity in India," says Lord Lawrence, "does not by any means give an adequate result of missionary labours. There are thousands of persons scattered over India who from the knowledge they have acquired either directly or indirectly through dissemination of Christian truth and Christian principles have lost all belief in Hinduism and Mohammedanism, and are in their conduct influenced by higher motives, who yet fear to make an open profession of the change in them lest they should be looked upon as outcasts and lepers by their own people." To some such a negative result may at first sight appear discouraging; but, read by the light of history, it marks a natural, almost a necessary, stage of transition from an ancient historical religion to Christianity. The Brahma Somaj is not the first instance where a system too vague and shadowy and too deficient in the elements of a permanent religion has filled the interval between the abandonment of the old and the acceptance of a new faith. The cultured classes amongst the Greeks and Romans experienced in their day, after the popular mythology had ceased to satisfy, a period of semi-scepticism before Christianity had secured its hold. Meantime in India the indirect agencies which are at work—the results of war and conquest, of European science and European literature, of the telegraph and the railway, the book and the newspaper, the college and the school, the change of laws hallowed by immemorial usage, the disregard of time-honoured prejudices, the very presence of Europeans in all parts of the country—all these various influences are gradually bringing about results analogous to that to which Sir James Mackintosh referred in a conversation with Henry Martyn, when the Oriental world was made Greek by the successors of Alexander in order to make way for the religion of Christ. But when to these indirect influences we add the effects of direct missionary instruction, of training schools like those of the Free Church of Scotland in Madras, of Bishop Sargent in Tinnevelly, of Bishop Cotton in the North-West Provinces, of Zenana missions now carried on on an extensive scale amongst the female population, of the numerous missionary presses at work circulating thousands of copies of the Holy Scriptures and of Christian books, it is obvious that, small and insignificant as these agencies may seem compared with the magnitude of the work required to be done, there has been a great advance made during recent years. The present century of missions may favourably compare with the primitive and mediæval ages of the church, and the continuity of the missionary spirit operating, as we have seen, after long periods of stagnation and depression is the best guarantee of its ultimate and more complete success at the close of the present epoch, during which, to use Karl Ritter's expression, "almost all the rivers of the earth have begun to run in double currents, and nearly all the seas and rivers have become the seas and rivers of civilization." (G. F. M.)

[1] *Abstract of Church Missionary Society's Report for* 1879, p. 13.

[2] *Report of the Propagation Society for* 1879, p. 31 *sq.*

MISSISSIPPI. The territory drained by the Mississippi river and its tributaries includes the greater part of the United States of America lying between the Alleghany Mountains on the east and the Rocky Mountains on the west, and has an area (1,244,000 square miles) considerably larger than all central Europe. The central artery through which the drainage of this region passes is called the Mississippi river for about 1300 miles above its mouth. The name is then usurped by a tributary, while the main



The Mississippi and its Tributaries.

stream becomes known as the Missouri. From its remote sources in the Rocky Mountains to the Gulf of Mexico the total length of the river is about 4200 miles. The other principal tributaries are the Ohio, the Arkansas, and the Red River, but the Yazoo and the St Francis often make dangerous contributions in seasons of flood.

The tables given below exhibit the hydraulic features of the Mississippi and its principal tributaries.

Below the influx of the Ohio the Mississippi traverses alluvial bottom lands liable to overflow in flood seasons. The soil is of inexhaustible fertility, producing large crops of corn in the northern portion, cotton in the middle district, and sugar, rice, and orange groves near the mouth. These bottom lands, averaging about 40 miles in width, extend from north to south for a distance of 500 miles, having a general southern slope of 8 inches to the mile. The river winds through them in a devious course for 1100 miles, occasionally on the east side washing bluffs from 100 to 300 feet in height, but usually confined by banks of its own creation, which, as with all sediment-bearing rivers of like character, are highest near the stream itself. The general lateral slope towards the foot hills is about 6 inches

in 5000 feet, but the normal fall in the first mile is about 7 feet. Thus apparently following a low ridge through the bottom lands, the tawny sea sweeps onward with great velocity, eroding its banks in the bends and rebuilding them on the points, now forming islands by its deposits, and now removing them as the direction of the flow is modified by the never-ending changes in progress. Chief among such changes is the formation of cut-offs. Two eroding bends gradually approach each other until the water forces a passage across the narrow neck. As the channel distance between these bends may be many miles, a cascade perhaps 5 or 6 feet in height is formed, and the torrent rushes through with a roar audible for miles. The banks dissolve like sugar. In a single day the course of the river is changed, and steamboats pass where a few hours before the plough had been at work. The checking of the current at the upper and lower mouths of the abandoned channel soon obstructs them by deposit, and forms in a few years one of the characteristic crescent lakes which are so marked a feature on the maps.

The total area of the bottom lands is about 32,000 square miles, of which only a narrow strip along the immediate banks of the main river and of its principal bayous and tributaries has even yet been brought under cultivation. A proper system of protection against overflow would throw open 2,500,000 acres of rich sugar land, 7,000,000 acres of the best cotton land in the world, and 1,000,000 acres of corn land of unsurpassed fertility.

The work of embankment began in 1717, when the engineer De la Tour erected a dyke or levee 1 mile long to protect the infant city of New Orleans from overflow. Progress at first was slow. In 1770 the settlements extended only 30 miles above and 20 miles below New Orleans; but by 1828 the levees, although quite insufficient in dimensions, had become continuous nearly to the mouth of Red River. In 1850 a great impulse was given to systematic embankment by the U.S. Government, which gave over to the several States all unsold swamp and overflowed lands within their limits to provide a fund for reclaiming the districts liable to inundation. The action

Tributaries of the Lower Mississippi.

River.	Distance from Mouth.	Elevation above Sea.	Width between Banks.	Range between High and Low Water.	High Water Cross Section.	Remarks.
	Miles.	Feet.	Feet.	Feet.	Square Feet.	
Missouri—						
Source	2,908	6,800?	...	...	...	Area of basin, 518,000 square miles; rainfall, 20·9 inches; annual discharge, $3\frac{78}{100}$ billions [*i.e.*, 3,780,000,000,000] cubic feet; ratio between drainage and rainfall, $\frac{15}{100}$; mean discharge per second, 120,000 cubic feet.
Three Forks	2,824	4,319	...	...	...	
Fort Benton	2,644	2,845	1,500	6	...	
Fort Union	1,894	2,188	1,500	...	...	
Sioux City	842	1,065	2,500	...	...	
St Joseph	484	756	3,000	20	75,000	
Mouth	0	381	3,000	35	75,000	
Upper Mississippi—						
Source	1,330	1,680	...	...	...	Area of basin, 169,000 square miles; rainfall, 35·2 inches; annual discharge, $3\frac{2}{10}$ billions cubic feet; ratio between drainage and rainfall, $\frac{24}{100}$; mean discharge per second, 105,000 cubic feet.
Swan River	998	1,290	120	...	...	
St Paul	658	670	1,200	20	100,000	
Rock Island	310	505	5,000	16	100,000	
Mouth	0	381	5,000	35	100,000	
Ohio—						
Coudersport	1,265	1,649	...	...	...	Area of basin, 214,000 square miles; rainfall, 41·5 inches; annual discharge, 5 billions cubic feet; ratio between drainage and rainfall, $\frac{24}{100}$; mean discharge per second, 158,000 cubic feet.
Pittsburg	975	699	1,200	45	50,000	
Cincinnati	515	432	...	42	...	
Mouth	0	275	3,000	51	150,000	
Arkansas—						
Source	1,514	10,000	150	...	...	Area of basin, 189,000 square miles; rainfall, 29·3 inches; annual discharge, 2 billions cubic feet; ratio between drainage and rainfall, $\frac{15}{100}$; mean discharge per second, 63,000 cubic feet.
Bent's Fort	1,289	3,672	5,000	6	30,000	
Great Bend	992	1,658	5,000	...	...	
Fort Smith	522	418	1,500	25	70,000	
Little Rock	250	252	1,500	35	70,000	
Mouth	0	162	1,500	45	70,000	
Red River—						
Near source	1,200	2,450	2,000	8	12,000	Area of basin, 97,000 square miles; rainfall, 39 inches; annual discharge, $1\frac{8}{10}$ billions cubic feet; ratio between drainage and rainfall, $\frac{20}{100}$; mean discharge per second, 57,000 cubic feet.
Preston	820	641	2,000	...	...	
Shreveport	330	180	800	25	40,000	
Mouth	0	54	800	45	40,000	

The Lower Mississippi.

	Distance from Mouth.	High Water Elevation above Sea.	Fall per Mile.	Width between Banks.	Least Low Water Depth upon the Bars.	Range between High and Low Water.	Area of Cross Section at High Water.	Remarks.
	Miles.	Feet.	Feet.	Feet.	Feet.	Feet.	Square Feet.	
Mouth of Missouri	1,286	416·0	...	...	2·0	..	...	Drainage area, 1,244,000 square miles; rainfall, 30·4 inches; annual discharge (including three outlet bayous), $21\frac{7}{10}$ billions of cubic feet; ratio between drainage and rainfall, $\frac{24}{100}$; mean discharge per second, 675,000 cubic feet.
St Louis	1,270	408·0	0·500	...		37·0	...	
Cairo	1,097	322·0	0·497	4,470	5·0	51·0	191,000	
Columbus	1,076	310·0	0·571			47·0		
Memphis	872	221·0	0 436			40·0		
Gaines landing	647	149·0	0·320	4,080	6·0	...	199,000	
Natchez	378	66·0	0·309			51·0		
Red River landing	316	49·5	0·266			44·3		
Baton Rouge	245	33·9	0·220	3,000	...	31·1	200,000	
Donaldsonville	193	25·8	0·156		...	24·3		
Carrollton	121	15·2	0·147	2,470	...	14·4	199,000	
Fort St Philip	37	5·2	0·119		...	4·5		
Head of Passes	17	2·9	0·115		...	2·3		
Gulf	0	0·0	0·171	...	...	0·0	...	

resulting from this caused alarm in Louisiana, for the great bottom lands above were believed to act as reservoirs to receive the highest flood wave; and it was imagined that if they were closed by levees the lower country would be overwhelmed whenever the river in flood rose above its natural banks. The aid of the Government was invoked, and Congress immediately ordered the necessary investigations and surveys. This work was placed in charge of Captain (now General) Humphreys, and an elaborate report covering the results of ten years of investigation was published just after the outbreak of the civil war in 1861. The second of the tables given above, and indeed most of the physical facts respecting the river, are quoted from this standard authority.

To understand the figures of the table it should be noted that at the mouth of Red River, 316 miles above the passes, the water surface at the lowest stage is only $5\frac{2}{10}$ feet above the level of the Gulf, where the mean tidal oscillation is about $1\frac{2}{10}$ feet. The river channel in this section is therefore a freshwater lake, nearly without islands, 2600 feet wide and 100 feet deep along the deepest line. At the flood stage the surface rises 50 feet at the mouth of Red River, but of course retains its level at the Gulf, thus giving the head necessary to force forward the increased volume of discharge. Above the mouth of Red River the case is essentially different. The width increases and the depth decreases; islands become numerous; the oscillation between high and low water varies but little from 50 feet until the mouth of the Ohio is reached—a distance of about 800 miles. Hence the general slope in long distances is here nearly the same at all stages, and the discharge is regulated by the varying resistances of cross section, and by local changes in slope due to the passage of flood waves contributed by the different tributaries. The effect of these different physical conditions appears in the comparative volumes which pass through the channel. At New Orleans the maximum discharge hardly reaches 1,200,000 cubic feet per second, and a rising river at high stages carries only about 100,000 cubic feet per second more than when falling at the same absolute level; while just below the mouth of the Ohio the maximum flood volume reaches 1,400,000 cubic feet per second, and at some stages a rising river may carry one-third more water than when falling at the same absolute level.

The percentage of sedimentary matter carried in suspension by the water varies greatly at different times, but is certainly not dependent upon the stage above low water. It is chiefly determined by the tributary whence the water proceeds, but is also influenced by the caving of the banks, which is always excessive when the river is rapidly falling after the spring flood. In long periods the sedimentary matter is to the water by weight nearly as 1 to 1500, and by bulk as 1 to 2900. The amount held in suspension and annually contributed to the Gulf constitutes a prism 1 mile square and 263 feet high. In addition to this amount a large volume, estimated at 1 mile square and 27 feet high annually, is pushed by the current along the bottom and thus transported to the Gulf.

The mean annual succession of stages for long periods is quite uniform, but so many exceptions are noted that no definite prediction can safely be made for any particular epoch. The river is usually lowest in October. It rises rapidly until checked by the freezing of the northern tributaries. It begins to rise again in February, and attains its highest point about the 1st of April. After falling a few feet it again rises until, early in June, it attains nearly the same level as before. After this it rapidly recedes to low-water mark. As a rule the river is above mid-stage from January to August inclusive, and below that level for the remainder of the year.

It has been established by measurement and observation that the great bottom lands above Red River before the construction of their levees did not serve as reservoirs to diminish the maximum wave which passed through Louisiana in great flood seasons. They had already become filled by local rains and by water escaping into them from the Mississippi through numerous bayous, so that at the date of highest water the discharge into the river near their southern borders was fully equal to the volume which the wave had lost in passing along their fronts.

In fine, the investigations between 1850 and 1860 established that no diversion of tributaries was possible; that no reservoirs artificially constructed could keep back the spring freshets which caused the floods; that the making of cut-offs, which had sometimes been advocated as a measure of relief, so far from being beneficial, was in the highest degree injurious; that, while outlets within proper limits were theoretically advantageous, they were impracticable from the lack of suitable sites; and, finally, that levees properly constructed and judiciously placed would afford protection to the entire alluvial region.

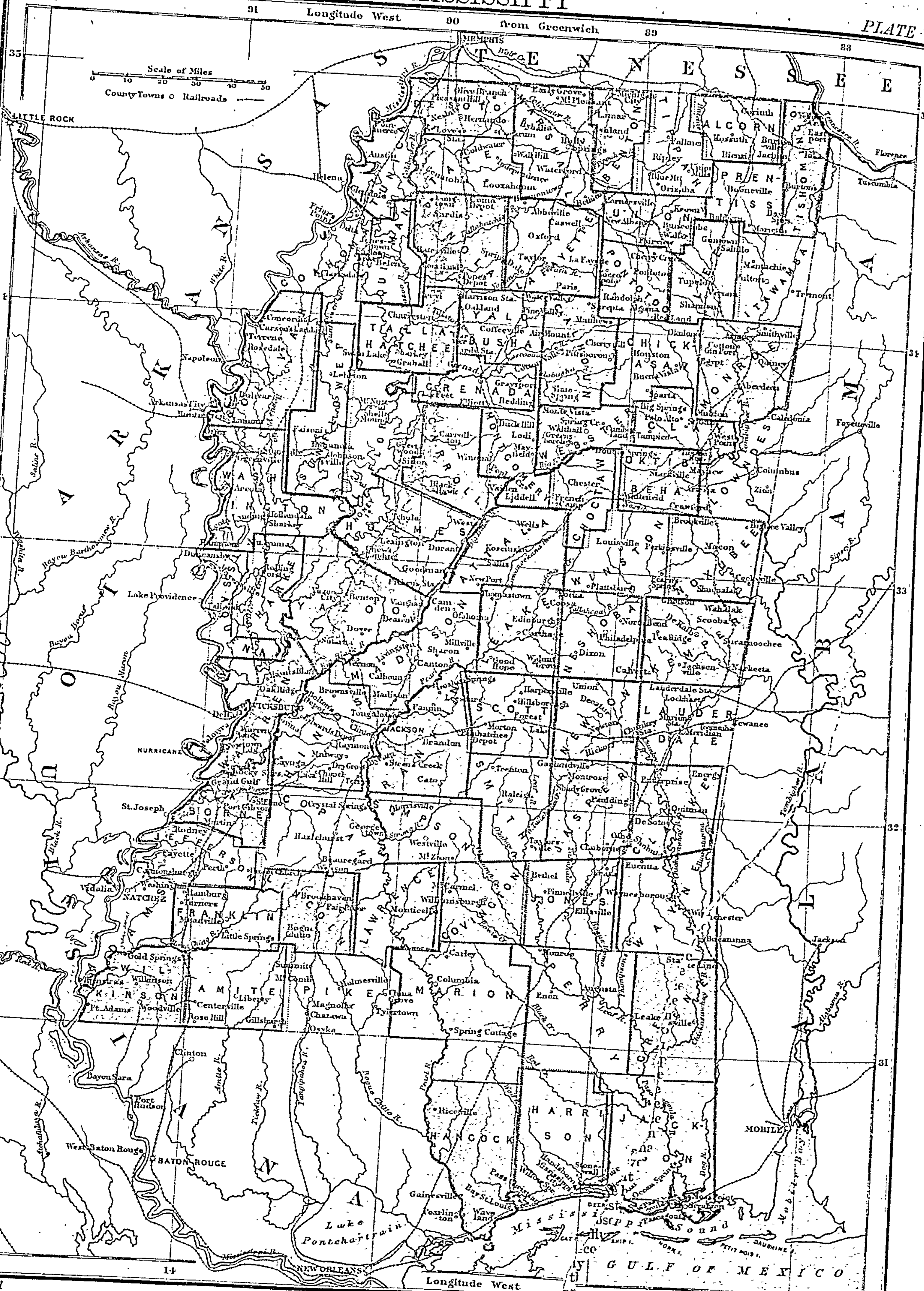
During the civil war (1861–65) the artificial embankments were neglected; but after its close large sums were expended by the States directly interested in repairing them. The work was done without concert upon defective plans, and a great flood early in 1874 inundated the country, causing terrible suffering and loss. Congress, then in session, passed an Act creating a commission of five engineers to determine and report on the best system for the permanent reclamation of the entire alluvial region. Their report, rendered in 1875, endorsed the conclusions of that of 1861, and advocated a general levee system on each bank. This system comprised—(1) a main embankment raised to specified heights sufficient to restrain the floods; and (2), where reasonable security against caving required considerable areas near the river to be thrown out, exterior levees of such a height as to exclude ordinary high waters but to allow free passage to great floods, which as a rule only occur at intervals of five or six years. The back country would thus be securely protected, and a safe refuge would be provided for the inhabitants and domestic animals living upon the portion subject to occasional overflow. An engineering organization was proposed for constructing and maintaining these levees, and a detailed topographical survey was recommended to determine their precise location. Congress promptly approved and ordered the survey; but strong opposition on constitutional grounds was raised to the construction of the levees by the Government.

In the meantime complaints began to be heard respecting the low-water navigation of the river below the mouth of the Ohio. Forty-three places above the mouth of Red River afforded depths of less than 10 feet, and thirteen places depths less than 5 feet, the aggregate length of such places being about 150 miles. A board of five army engineers, appointed in 1878 to consider a plan of relief, reported that 10 feet could probably be secured by narrowing the wide places to about 3500 feet with hurdle work, brush ropes, or brush dykes designed to cause a deposit of sediment, and by protecting caving banks, when necessary, by such light and cheap mattresses as experience should show to be best suited to the work. Experiments in these methods were soon begun upon the river above Cairo, and have since proved of decided benefit.

In June 1879 Congress created a commission of seven members to mature plans to correct, permanently determine, and deepen the channel, to protect the banks of the river, to improve and give safety to navigation, to prevent destructive floods, and to promote and facilitate commerce. Up to 1882 appropriations amounting to £1,285,000 were made to execute the plans of this commission, but with provisos that none of the funds were to be expended in repairing or building levees for the protection of land against overflow, although such levees might be constructed if necessary to deepen the channel and improve navigation. Acting under this authority, the commission have allotted considerable sums to repair existing breaks in the levees; but their chief dependence is upon contracting the channel at low water by promoting lateral deposits, and upon protecting the high-water banks against caving by mats of brush, wire, &c., ballasted where necessary with stone,—substantially the plans proposed by the army board of 1878.

The bars at the efflux of the passes at the mouth of the Mississippi have long been recognized as serious impediments to commerce. The river naturally discharges through three principal branches, the south-west pass, the south pass, and the north-east pass, the latter through two channels, the most northern of which is called Pass à l'Outre. The ruling depth on the several bars varies with the discharge over them, which in turn is controlled by the successive advances of the passes. In the natural condition the greatest

MISSISSIPPI



ENCYCLOPÆDIA BRITANNICA, NINTH EDITION

depth does not exceed 12 or 13 feet. The first appropriation by Congress to secure increased depth was made in 1837, and was expended in an elaborate survey and in a system of dredging by buckets, but the plan of a ship canal was also discussed. At the next appropriation, made in 1852, a board of officers, appointed by the war department, recommended trying in succession—(1) stirring up the bottom by suitable machinery, (2) dredging by buckets, (3) constructing parallel jetties 5 miles long at the south-west pass, to be extended as found necessary, (4) closing lateral outlets, and (5) constructing a ship canal. A depth of 18 feet was secured by the first plan, and was maintained until the available funds were exhausted. Under the next appropriation (1856) an abortive attempt was made to apply the plan of jetties to the south-west pass. This failed from defects in execution by the contractors, but a depth of 18 feet was finally secured by dredging and scraping. The report of 1861 discussed the subject of bar formation at length. Although it approved the plan of jetties and closure of outlets as correct in theory, the stirring up of the bottom by scrapers during the flood stages of the river (six months annually) was recommended by it as the most economical and least objectionable. After the war this recommendation was carried into effect for several years with improved machinery, giving at a moderate annual cost a depth at times reaching 20 feet at extreme low water, but experience indicated that not much more than 18 feet could be steadily maintained. This depth, entirely satisfactory at first, soon became insufficient to meet the growing demands of commerce, and in 1873 Major Howell, the engineer in charge, revived the project of a ship canal. The subject was discussed carefully by a board of army engineers, the majority approving a ship canal. In 1874 Congress constituted a special board which, after visiting Europe and examining similar works of improvement there, reported in favour of constructing jetties at the south pass, substantially upon the plan used by Mr Caland at the mouth of the Meuse; and in March 1875 Captain J. B. Eads and associates were authorized by Congress to open by contract a broad and deep channel through the south pass upon the general plan proposed by this board. This contract called for "the maintenance of a channel of 30 feet in depth and 350 feet in width for twenty years" by "the construction of thoroughly substantial and permanent works by which said channel may be maintained for all time after their completion." The jetties were to be not less than 700 feet apart. The sum of £1,080,000 was to be paid for obtaining this channel, and £412,000 for maintaining it for twenty years. In addition, the contractors were authorized to use any materials on the public lands suitable for and needed in the work. The south pass was $12\frac{9}{10}$ miles long. It had an average width of 730 feet and a minimum interior channel depth of 29 feet. The distance from the 30-foot curve inside the pass across the bar to the 30-foot curve outside was 11,900 feet. The minimum depth at average flood tide on the bar was about 8 feet. The discharge at the mouth was about 57,000 cubic feet of water per second, transporting annually about 22 million cubic yards of sediment in suspension to the Gulf. A small island and shoal existed at the head of the pass, the channel there having a minimum depth of 17 feet. The work was begun on June 2, 1875, and has been so far successful that during the year ending June 30, 1882, a channel was maintained having a least depth of 30 feet between the jetties and extending through the bar. Its least width was 20 feet, the average being 105 feet. The 26-foot channel had a least width of 200 feet, except for a few days. In the pass itself the 26-foot channel had a least width of 50 feet. A very powerful dredge-boat was at work between and beyond the jetties 87 days, of which 51 were devoted to the channel in the Gulf. A deepening of 6 feet has occurred in Pass à l'Outre near its head since 1875. Up to the present time the work has proved of great benefit to the commerce of New Orleans.

For further details, see RIVER ENGINEERING. (H. L. A.)

VI. MISSISSIPPI, one of the Southern States of the American Union, derives its name from the river which for more than 500 miles forms its western boundary between the 35th and 31st parallels of north latitude, separating it from Arkansas and Louisiana. The boundary with the latter State is continued along the 31st parallel, for 110 miles, to the Pearl river, and then down the Pearl to its mouth. The Gulf of Mexico, eastward from the mouth of Pearl river, completes the southern boundary. On the north the 35th parallel, from the Mississippi river to the Tennessee, separates the State from Tennessee, and the boundary then follows the latter river to the mouth of Bear Creek, in 34° 53′ N. lat. and 88° 15′ W. long. The eastern boundary of the State, separating it from Alabama, follows a line drawn from the mouth of Bear Creek about seven degrees west of south to what was "the north-western corner of Washington county on the Tombigbee," and thence due south to the Gulf of Mexico. Ship, Horn, Cat, and Petit Bois Islands, and those nearer the shore, form a part of Mississippi. The extreme length of the State, north and south, is 330 miles, and its maximum breadth is 188 miles. Under the United States surveys, begun in 1803, the State has been divided into townships and sections, except such parts as were at the first owned by individuals. The area of the State is given in the census reports for 1880 as 46,340 square miles.

Topography.—There are no mountains in Mississippi, but a considerable difference of level exists between the continuously low, flat, alluvial region lying along and between the Mississippi and Yazoo rivers, called "the Bottom," and nearly all the remainder of the State, which is classed as upland. The latter part, comprising five-sixths of the whole, is an undulating plateau whose general elevation above the water of the Gulf of Mexico increases to 150 feet within a few miles of the coast, and varies elsewhere from 150 to 500 or 600 feet. Some exceptional ridges are probably 800 feet high. The streams of this region flow in valleys varying in width from a few hundred yards to several miles. The fall of each river is not great, and is quite uniform. Usually a considerable part of the valley of each larger stream is several feet above its present high water mark, and forms the "hommock," or "second bottom" lands. On some of the rivers the lowest part of the valley, subject to overflow, is several miles in width, and bears a resemblance to the Mississippi Bottom.

Ridges or plateaus everywhere in the upland region divide the contiguous basins of creeks and rivers, descending more or less abruptly to their valleys. In the north-eastern part of the State, almost level prairies cover large areas overlying a Cretaceous formation called Rotten Limestone.

A line of abrupt bluffs, extending southward from the north-west corner of the State, divides the upland region from the Bottom, where the general surface lies below the high-water level of the Mississippi river. A few low ridges, running north and south, and embracing about 200,000 acres, are barely above high water. The cultivated lands in the Bottom lie on these, and on the borders of the rivers and the numerous lakes and bayous, where the surface is slightly elevated. Low swamps or marshes, in which flourish large cypress trees (*Taxodium distichum*), lie between the streams, and frequently receive the surface drainage from their banks. Large forest trees and dense cane-brakes (*Arundinaria gigantea*) occupy the drier ground. The Mississippi river is prevented from flooding the Bottom during high water by a system of levees or embankments built by a fund derived partly from taxation on the land and partly from the proceeds of the sale of public lands in the State classed as "swamp lands," which were given over for this purpose by Congress. The only compensation for the injury done when breaks in the levees ("crevasses") occur is the deposit of alluvial matter left by the overflow, which adds to the productiveness of the already wonderfully fertile soil. The present levee system usually protects about one-fourth of the 4,000,000 acres in the Bottom. Many crescent-shaped lakes ("cut-offs") occur in the Bottom. Similar phenomena present themselves in the channels of the other rivers having wide bottoms.

The volume of water in the streams varies greatly during the year, and is usually largest between the months of January and April. During high water all the larger streams are navigable by steamboats. These ply upon the Mississippi, Tennessee, and Yazoo rivers throughout the whole year. The rivers flowing into the Gulf are much obstructed by sand-bars, and are chiefly used for floating logs to the saw-mills on the coast.

The best and only deep harbour on the coast is the well-protected roadstead inside of Ship Island. It has a depth of 27 feet, a firm clay bottom, and is readily accessible to lighters from the shallower harbours along the coast.

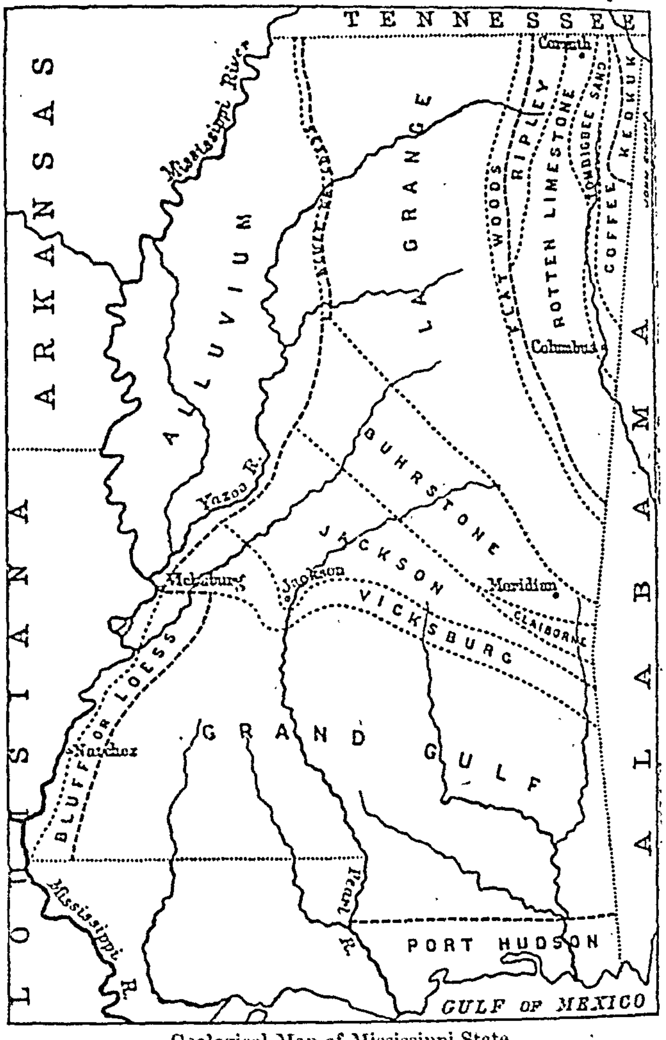
Climate.—Near the waters of the Gulf of Mexico the climate is much milder than in the northern parts of the State. On the southern borders the temperature rarely falls to 32° Fahr., or exceeds 95°, the annual mean being about 68°. The orange, lemon, almond, banana, and olive can be grown without protection. In the latitude of Vicksburg the temperature ranges from 98° to 20°, very rarely lower; the annual mean is 65°. The range in the northern part of the State is from 98° to 15°, or rarely 10°, and the annual mean is 61°. The first and last hoar-frosts occur, in the central parts of the State, usually in the latter parts of October and March. The ground is seldom frozen to the depth of 3 inches, and only for a few days at a time. The rainfall on the coast is 60 to 65 inches per annum, and at the northern boundary 50 inches. While about two-thirds of this precipitation occurs in winter and spring, a month seldom passes without several inches of rainfall.

Land and sea breezes in the south, and variable winds elsewhere, make the heat of summer tolerable. In healthfulness Mississippi compares favourably with other States. The average death-rate of thirteen States, variously situated, as given in the census of 1880, is 1·38 per cent.; that of Mississippi is 1·19 per cent. Where the surface is flat and poorly drained malarial fevers are prevalent during the warm season. Yellow fever has become epidemic after importation, but strict quarantine has been successful in preventing it.

Geology.—In accordance with an Act of the legislature passed in 1850, an agricultural and geological survey of the State was begun, which continued, with interruptions, until 1871. Two reports have been published, one in 1854 and another in 1860.

The geological structure of the State is comparatively simple, and closely related to that of the adjacent States. The older formations are nearly all overlaid by deposits of the Quaternary period, which will be described last. In the extreme north-eastern portion are found the oldest rocks in the State,—an extension of the Subcarboniferous formation which underlies the Warrior coal-fields of Alabama. The strata here show some traces of the upheaval which formed the Appalachian mountain chain, whose south-west termination is found in Alabama. When this chain formed the Atlantic mountain-border of the continent, excepting this north-east corner, Mississippi had not emerged from the waters of the ancient Gulf of Mexico. As the shore-line of the Gulf slowly receded southward and westward, the sediment at its bottom gradually came to the surface, and constituted the Cretaceous and Tertiary formations of this and adjacent States. Wherever stratification is observed in these formations in Mississippi, it shows a dip west and south of 20 or 30 feet to the mile. The Cretaceous region includes, with the exception of the Subcarboniferous, all that part of the State eastward of a line cutting the Tennessee boundary in 89° 3′ W. long., and drawn southward and eastward through the towns of Ripley, Pontotoc, and Starkville, crossing into Alabama in latitude 32° 45′. Four groups of Cretaceous strata have been determined in Mississippi, defined by lines having the same general direction as the one just described. The oldest, bordering the Subcarboniferous, is the Eutaw or Coffee group, characterized by bluish-black or reddish laminated clays, and yellow or grey sands, containing lignite and fossil resin. Westward and southward to the city of Columbus is the Tombigbee sand group, consisting chiefly of fine-grained micaceous sands of a greenish tint, with many marine fossils. Next in order, westward and southward, is the Rotten Limestone group, made up of a material of great uniformity,—a soft chalky rock, white or pale blue, composed chiefly of tenacious clay, and white carbonate of lime in minute crystals. Borings show the total thickness of this group to be about 1000 feet. Fossils are abundant, but species are few. The latest Cretaceous is the Ripley group, lying west of the northern part of the last-named group, and characterized by hard crystalline white limestones, and dark-coloured, micaceous, glauconitic marls, whose marine fossils are admirably preserved. One hundred and eighty species have been described. The total thickness of the Cretaceous is about 2000 feet. Deposits of the Tertiary period form the basis of more than half the State, extending from the border of the Cretaceous westward nearly or quite to the Yazoo and Mississippi Bottom, and southward to within a few miles of the Gulf coast. Seven groups of the Tertiary strata have been distinguished. Beginning nearest the Cretaceous, the Flatwoods group is characterized by grey or white clays, and a soil which responds poorly to tillage. The Lagrange group, lying to the west of the last, is marked by grey clays and sands, fossil plants, and beds of lignite or brown coal, sometimes 8 feet in thickness. The Buhrstone group, lying south-westward from the last, is characterized by beds of white siliceous clays, and of silicified shells, and sandy strata containing glauconite in valuable quantities. The Claiborne group lies south of the last, and is slightly developed in Mississippi, but well-marked in Alabama. The Jackson group, south-west of the last two, is made up chiefly of soft yellowish limestones or marls, containing much clay, and sandy strata with glauconite. Zeuglodon bones and other marine fossils are abundant. The Vicksburg group lies next in order south-westward, and is characterized by crystalline limestones and blue and white marls. Marine fossils are very abundant. More than one hundred and thirty species have been determined. The Grand Gulf group, showing a few fossil plants and no marine fossils, extends southward from the last to within a few miles of the coast.

The oldest formation of the Quaternary period is the "orange-sand" or "stratified drift," which immediately overlies all the Cretaceous groups except the prairies of the Rotten Limestone, and all the Tertiary except the Flatwoods and Vicksburg groups and parts of the Jackson. Its depth varies from a few feet to over 200 feet, and it forms the body of most of the hills in the State. Its materials are pebbles, clays, and sands of various colours from white to deep red, tinged with peroxide of iron, which sometimes cements the pebbles and sands into compact rocks. The shapes of



Geological Map of Mississippi State.

these ferruginous sandstones are very fantastic,—tubes, hollow spheres, plates, &c., being common. The name stratified drift is used by the geologist of Alabama to indicate its connexion with the northern drift. The fossils are few, and in some cases probably derived from the underlying formations. Well-worn pebbles of amorphous quartz, agate, chalcedony, jasper, &c., are found in the stratified drift along the western side of the Tertiary region of the State, and from Columbus northward. "While this formation is not well understood, it seems tolerably well established that the melting of the great glaciers of the north furnished the water which brought with it fragments of the rocks over which it passed, and flowed into the Gulf with a current which was most rapid where the pebbles were dropped, but overspread the remainder of the State with a gentler flow, leaving sands and clays" (E. A. Smith). The second Quaternary formation is the Port Hudson, occurring within 20 miles of the Gulf coast, and probably outcropping occasionally in the Mississippi Bottom. Clays, gravel, and sands, containing cypress stumps, drift-wood, and mastodon bones, are characteristic. The loess or bluff formation lies along the bluffs bordering the Bottom, nearly continuously through the State. Its fine-grained, unstratified silt contains the remains of many terrestrial animals, including fifteen mammals.

The surface and subsoil of nearly all the upland region of Mississippi, the southern part being the exception, is composed of yellow loam or brick-clay containing no fossils, and showing no stratification. The soil of the Rotten Limestone region is similar in its general make up, but is black, and contains more lime and clay. Both are regarded as an independent aqueous deposit, posterior to the stratified drift and bluff formations, and anterior to the alluvium of the present epoch. The "second bottoms," probably, are later than the yellow loam, and belong to the "terrace epoch." The latest formation, alluvium, is strongly marked, and covers a large area in the Yazoo and Mississippi Bottom, and along other streams.

The following are the equivalents of the Mississippi groups in Dana's *Geology*:—

Quaternary	20*d* Alluvium		Alluvium.
	20*c* Loam and loess		Loam and loess.
	20*b* Port Hudson		Port Hudson.
	20*a* Drift		Stratified drift.
Tertiary	19*a* Eocene	*Upper*	Grand Gulf. Vicksburg.
		Middle	Jackson. Claiborne.
		Lower	Buhrstone, Lagrange. Flatwoods.
Cretaceous	18*b* Upper		Ripley. Rotten Limestone.
	18*a* Lower		Tombigbee. Coffee.
Subcarboniferous			Keokuk.

Minerals.—Metallic ores are not found in Mississippi in paying quantities. The only valuable minerals are sandstones and limestones, marls, sands, lignite or brown coal, and fire-clays. None of these have been extensively brought into market. Potable water is found almost everywhere. Artesian wells furnish it in the Rotten Limestone region, when bored into the underlying Coffee strata.

Fauna.—Mississippi affords perhaps no species which are not found in the neighbouring States. There are thirty or forty species of *Mammalia*, the most remarkable being the American opossum, still quite abundant. The deer (*Cervus virginianus*), black bear (*Ursus americanus*), wolves (*Canis lupus* and *Lupus americanus*), catamount (*Felis concolor*), and wild-cat (*Lyncus rufus*) have much decreased in number, and may, like the buffalo and elk, shortly become extinct. About one hundred and fifty species of birds are found during at least part of the year. Many are seen only *in transitu*, and about twenty species from the north spend the winter here. The mocking bird (*Mimus polyglottus*), the most remarkable songster, is very abundant. The wild turkey (*Meleagris gallipavo*) survives by virtue of its wary and watchful character. Over fifty species of *Reptilia* have been found, prominent among which is the alligator (*A. mississippiensis*), which attains a length of 12 or 15 feet, and is common in the southern river bottoms. The rattlesnake, moccasin, and copperhead, venomous serpents, are occasionally found. About half of the sixty-three species of fish abounding in the fresh and salt waters of the State are valuable for food. The edible oysters and crustaceans of the coast are remarkably fine.

Flora.—Originally nearly the entire State was covered with a growth of forest trees of large size, mostly deciduous. The undergrowth was kept down by annual burnings by the natives, and the ground became carpeted with grasses and herbs. Over 120 species of forest trees are found; many valuable ones are abundant, and their timber constitutes a large item in the resources of the State. Of the 15 species of oak the most valuable are the live-oak (*Q. virens*), found near the coast, and the white-oak (*Q. alba*), widely distributed. The cypress (*Taxodium distichum*) is very abundant in the bottoms. Various species of hickory, the chestnut, black walnut, sweet gum, cucumber tree, cottonwood (*Populus deltoides*), red cedar, elms, holly, magnolias, maples, ash, persimmon, sycamore, tupelo, and many others valuable for their timber, are abundant and of large size. The long-leaved pine (*P. australis*) forms the principal forest growth south of lat. 32° 15'. It attains a diameter of 2 or 3 feet, has a tall and shapely trunk, and its timber is unsurpassed in the variety of its uses. The census reports estimate the merchantable timber of this species now standing in the State at 18,200,000,000 feet, board measure. The amount cut in 1880 was 108,000,000 feet. The short-leaved pine (*P. mitis*), almost as valuable, is found in various parts, the quantity now standing being estimated at 6,775,000,000 feet. The total value of the pine timber of the State is about $250,000,000.

Agriculture is the leading industry in Mississippi. Over 300,000 of the population are directly engaged in the cultivation of 4,895,000 acres of land. The character of the soil is varied, and all is productive, except that in the Flatwoods region and in the district covered with long-leaved pine, where only the valleys are fertile. At least half the State is exceptionally fertile. Not more than one-fourth of the arable land has been brought into cultivation, and two millions of acres of the best lands in the State, lying in the Bottom, might be made arable by proper drainage.

Cotton is the chief agricultural product; in 1880 Mississippi ranked first among the States in the amount raised. The crop of 1879-80 amounted to 955,808 bales, worth $43,000,000. There were produced also of cotton seed 28,000,000 bushels, worth $3,000,000; of Indian corn, 21,340,800 bushels; of oats, 1,959,620 bushels; of wheat, 218,890 bushels; of rice, 1,718,950 lb. Small quantities of rye, barley, molasses, and tobacco, and abundant crops of potatoes, yams, pease, and all garden vegetables, are annually produced.

Fruits of various kinds flourish in many parts of the State, and, with early vegetables, are largely shipped to the northern markets in spring and early summer. The value of the cotton crop is about three times as great as that of all the other products of the soil, which are sometimes insufficient for home consumption. Economically this specialization of agriculture is to be regretted; but successful efforts are being made to diversify it by growing other crops to which the soil and climate are equally well suited.

Manufactures.—The principal articles manufactured are lumber, cotton and woollen goods, cotton seed oil, and agricultural implements.

Population.—The number of inhabitants according to the different census returns from 1850 is given in the following table:—

Census.	Total.	White.	Coloured.	Density per Sq. Mile.
1850	606,526	295,718	310,808	13·09
1860	791,314	353,910	437,404	17·07
1870	829,609	381,519	445,060	17·9
1880	1,131,592	479,371	652,221	24·42

Of the coloured population, mostly freedmen and their descendants, 1738 were Indians or half-breeds in 1880, and about 60,000 mulattoes. The whites own nearly all the farms and other real property. The total property valuation in the State decreased from $607,324,911 in 1860 to $209,197,345 in 1870, on account of the losses in war and the liberation of the slaves. There has been, however, a rapid increase in the last decade. The towns in the State have small populations: in 1880 Vicksburg had 11,814 inhabitants, Natchez 7058, and Jackson, the State capital, 5204.

Administration.—The three departments, legislative, executive, and judiciary, are similar to those of other States. The governor and other executive officers are elected for four years. The legislature, which meets biennially, is composed of forty senators, serving four years, and one hundred and twenty representatives, serving two years. These are apportioned to the seventy-four counties according to population, and elected by the people. The judiciary officers, consisting of three justices of the supreme court, twelve circuit judges, and twelve chancellors, are appointed by the governor with the consent of the senate. One attorney-general and twelve district attorneys are elected by the people. The State maintains a public school system, with separate schools for the two races, costing in 1880 $830,704, besides a State university and other schools of high grade for each of the races.

History.—Mississippi was first visited by Europeans in 1540, when the adventurous expedition of De Soto reached its northern parts. After the disastrous termination of this expedition no other Europeans visited this region until 1673, when Joliet and Père Marquette descended the Mississippi to lat. 33°. In 1682 La Salle and Tonty descended to the mouth of the river, and claimed the whole region drained by it for the king of France, giving it the name Louisiana. In 1699 the first colonists reached the coast of Mississippi, sent from France under Iberville. Settlements were made on Ship Island and Cat Island, and upon the mainland on the eastern side of Biloxi Bay, at Bay St Louis, and at Mobile. The colony did not prosper, and in 1712 Anthony Crozat obtained by charter from the king all the commercial privileges of the lower Mississippi valley. Under his management the colony languished, and in 1717 the king accepted the surrender of his charter, and granted another with more extended privileges to the "Western Company," or "Mississippi Scheme," with John Law as director-general, and Bienville as governor of the colony. Under this management the rich alluvial lands on the Mississippi river began to be occupied; tobacco, rice, and indigo were cultivated, and African slaves were introduced. Settlements were made near the present city of Natchez in 1720. Two years later, Law's company becoming bankrupt, much embarrassment in the colony followed, and troubles also began with the natives. On November 28, 1729, the Natchez Indians surprised and murdered about 200 of the white male residents, and made captives of about 500 women and children and negroes. A war followed, resulting in the destruction of the Natchez tribe. The representatives of the "Western Company" returned their franchises to the king in 1732, the number of colonists and slaves being then about 7000. After two unsuccessful campaigns against the Chickasaw Indians in the northern part of what is now Mississippi, Bienville was superseded by the Marquis de Vaudreuil in 1740.

By the treaty of Paris, in 1763, France ceded all her possessions east of the Mississippi river to England, excepting the island of New Orleans, ceded to Spain. The British province of West

Florida at first extended eastward from the Mississippi river along the Gulf coasts, with its northern limit at the 31st parallel of north latitude. Soon afterwards the northern boundary was fixed at a line drawn eastward from the point where the Yazoo river unites with the Mississippi.

Under British rule the Natchez country, which had been deserted since the massacre of 1729, and the southern part of the present State of Mississippi, rapidly filled with settlers, many of them emigrants from the Atlantic colonies. Cotton, indigo, and sugar were cultivated, and negro slaves continued to be freely introduced. During the revolutionary war of the Atlantic colonies, West Florida, being far removed, remained undisturbed until 1779. Spain and England being then at war, Galvez, the governor of New Orleans, aided by sympathizers with the revolutionary colonists, took possession of the whole of West Florida for the king of Spain. At the peace of 1783 England acknowledged the 31st parallel as the southern boundary of the United States, and ceded West Florida to Spain. The district between the 31st parallel and the parallel through the mouth of the Yazoo was therefore claimed by the United States and by Spain, the latter being in possession. After tedious negotiations the latter power relinquished the district in March 1798, and Congress at once formed it into "the Mississippi Territory," which extended from the Mississippi river eastward between the two above-mentioned parallels of latitude to the Chattahoochee river.

The State of Georgia claimed as a part of its domain all of the district east of the Mississippi river, and between the 31st and 35th parallels. In 1802 it ceded its claims to the Federal Government for certain considerations, and in 1804 Congress extended the imits of the Mississippi Territory northward to the 35th parallel. Nearly all of the Territory was then owned by the native Indians. The Choctaws occupied the southern part, and the Chickasaws the northern part of what is now the State of Mississippi. In 1812 the United States troops occupied Spanish West Florida, and the district east of Pearl river and south of lat. 31° was added to the Mississippi Territory. The Territory was divided by the present line between Alabama and Mississippi, and the State of Mississippi admitted into the Union in 1817. In 1830–32 the native tribes exchanged their lands for others west of the Mississippi river and were nearly all removed, and a rapid influx of settlers followed. In January 1861 the State seceded from the Federal Union, and, joining the Southern Confederacy, furnished a large number of troops during the civil war. It was the field of many important campaigns, and suffered great losses. Exhausted by the conflict, and harassed by processes of political reconstruction, the State was in a deplorable condition for several years. But within the last decade an era of prosperity commenced, marked by a large increase in population and great activity in agricultural and other pursuits.

Literature.—Gayarré, *History of Louisiana*; Monette, *History of the Valley of the Mississippi*, New York, 1846; Claiborne, *Mississippi as a Province, Territory, and State*, Jackson, 1880; Walles, *Agriculture and Geology of Mississippi*, Jackson, 1854; Hilgard, *Agriculture and Geology of Mississippi*, Jackson, 1860; Smith, *Outline of the Geology of Alabama*, Montgomery, 1880; Wall, *Handbook of Mississippi*, Jackson, 1882. (R. B. F.)

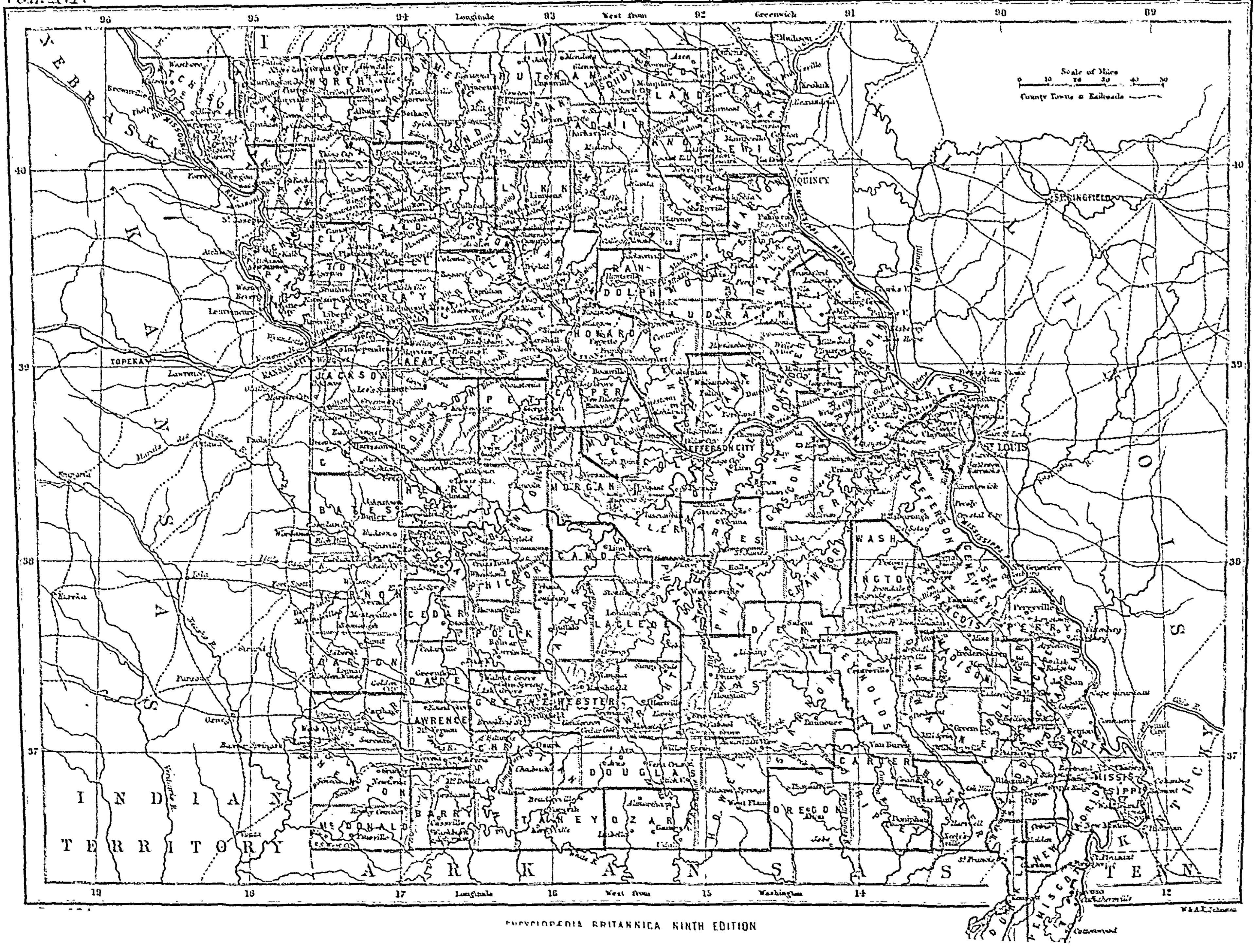
MISSOLONGHI, or Mesolonghi (Μεσολογγίον), a city of Greece, the chief town of the nomarchy of Acarnania and Ætolia, situated on the north side of the Gulf of Patras, about 7 miles from the coast, in the midst of a shallow lagoon, with a population of 6324 in 1879, is notable for the siege of two months which Mavrocordatos with a handful of men sustained in 1821 against a Turkish army 11,000 strong, and for the more famous defence of 1825–26 (see vol. xi. p. 125). Byron died there in 1824, and is commemorated by a cenotaph.

Plate VII. MISSOURI, a Central State of the American Union, lying almost midway between the Atlantic and the Rocky Mountains, British America and the Gulf of Mexico. Its eastern boundary is the Mississippi, separating it from Illinois, Kentucky, and Tennessee. North and south its boundaries with Iowa and Arkansas respectively are mainly coincident with the parallels of 40° 30′ and 36° 30′ N. lat.; but a small peninsula between the Mississippi and St François rivers stretches 34 miles farther south between Arkansas and Tennessee. The western border, with Nebraska, Kansas, and the Indian Territory, is nearly coincident with the course of the Missouri to the junction of that stream with the Kansas, and then follows the meridian of 17° 40′ W. of Washington (94° 43′ W. of Greenwich). The area of the State is 65,350 square miles, the extreme length from north to south 282 miles, the extreme width 348 miles. Missouri is divided into a northern and southern portion by the Missouri river, flowing 400 miles in a generally easterly direction from its junction with the Kansas to the point 12 miles above St Louis where it unites with the Mississippi. Northern Missouri has a surface broken and hilly, but not mountainous. It is mainly prairie land, well watered by streams, and fit for agriculture; but there is a good deal of timber in the eastern parts, especially along the bold bluffs of the two great rivers. Southern, Missouri is almost equally divided between timber land in the east and prairie in the west. In its south-western portion rises the table-land of the Ozark hills (highest point 1600 feet above the sea). The Osage, the Gasconade, and other streams flow northward and eastward into the Missouri. The south-eastern lowlands form an undulating country, readily drained after rain, with fertile ridges generally running north and south, occasional abrupt isolated hills, forests of oak, hickory, elm, maple, ash, locust, willow, persimmon, pecan, chestnut, and cherry trees, and in the lowest parts swamps and morasses. High rocky bluffs extend along the banks of the Mississippi from the mouth of the Meramec river to Ste Genevieve, rising sometimes precipitously to the height of 350 feet above the water, and low bottom lands with many lakes and lagoons extend from Ste Genevieve to the Arkansas border. The south-east corner of the State is 275 feet above the sea, the north-east corner 445 feet, and the north-west corner 1000 feet.

Climate.—The climate of Missouri, lying as it does far from the ocean and unprotected by mountain ranges, is one of extremes in heat and cold, moisture and drought. The Ozark range is high enough to influence the climate locally, but not to affect that of the whole State. The mean summer temperature for the ten years 1870–80 ranged from 75° in the north-west of the State to 78°·5 in the south-east; but the thermometer has been known to rise to 104°. The winter temperature averaged 33°·87 for the whole State, varying from 28°·5 in the north-west to 39°·5 in the south-east. In some winters the temperature hardly falls to zero; in others 20° below zero have been registered. The Mississippi at St Louis freezes over once in four or five years; but this is partly caused by the accumulations of floating ice coming down from the north. The river has closed as early as the first week in December, and, again, has remained open until the last week in February. It is in cold seasons sometimes passable for the heaviest teams. The Missouri river is often closed during the whole winter. The mean annual temperature of the State varies from 53° to 58°. The climate is, on the whole, dry; for, in spite of the abundant rains, especially in the spring, evaporation is so rapid that the atmosphere is rarely overloaded with moisture. April is the driest month. The greatest amount of rain falls in the south-eastern part of the State. An unusual amount of fair weather, prevailing clearness of sky, general salubrity of soil and climate, are chief among the natural advantages of this great State.

Geology.—The stratified rocks of Missouri belong to the following divisions:—Quaternary, Tertiary, Carboniferous, Devonian, Silurian, and Archæan. The Quaternary system comprises the drift, 155 feet thick; the bluff, 200 feet above the drift; then the bottom prairie, 35 feet thick; and on the surface the alluvium, 30 feet in thickness. Clays with strata of sands, marls, and humus form the alluvial bottoms of the two great rivers of the State, and make up a soil deep, light, and incomparably rich. Beneath the alluvium is found the bottom prairie, made up also of sands, clays, and vegetable moulds. This formation is found only in the bottom lands of the Missouri and Mississippi rivers, and more abundantly in those of the former. Numerous and well-preserved organic remains are found in the bottom prairie,

MISSOURI



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including the shells found in great quantities in the bluff and remains of the mastodon and many trees and plants. Below this formation, resting upon the drift, is the bluff. This rests upon the ridges and river bluffs, and thus is topographically higher, although geologically lower, than the bottom prairie. It is composed chiefly of a grey siliceous marl, coloured sometimes to a deep brown or red by the stains of oxide of iron. This formation extends along the bluffs of the Missouri from Fort Union to its mouth, and is found capping those of the Mississippi from Dubuque to the mouth of the Ohio. It is sometimes 200 feet thick; at St Joseph it is 140, at Booneville 100, at St Louis 50, in Marion county only 30 feet. This formation has interesting fossils (*Elephas primigenius*, &c.). The drift, the lowest of the Quaternary system, appears in the altered drift, the boulder formation, made up largely of the igneous and metamorphic rocks, with rocks from the Palæozoic strata upon which the others rest. Large boulders, five or six feet in diameter, are found, usually of granite or metamorphic sandstone; no fossils except a few logs in the altered drift have been found in this formation. The Tertiary formation in Missouri is composed of clays, shales, iron ores, sandstone, and sand, and extends along the bluffs and bottoms of the south-east part of the State. Iron ore is found in this formation in great abundance; sand of the best quality for glass-making and clays for pottery and stoneware also abound. Below the Tertiary bed are found rocks which strongly resemble Cretaceous beds found in other places in the United States. These strata are in such a state of irregularity and disturbance as to indicate the occurrence of some great movements after their deposition and before the formation of the Tertiary strata. The Upper Carboniferous system, or coal measures, made up of sandstone, limestone, marl, coal, and iron ores, covers an area of more than 23,000 square miles in Missouri, occupying the western and northern portions of the State. The supply of bituminous and cannel coals found here would seem to be well-nigh inexhaustible. In the Lower Carboniferous rock are found many varieties of limestone and sandstone. Among these are the Upper Archimedes Limestone, 200 feet; Ferruginous Sandstone, 195 feet; Middle Archimedes Limestone, 50 feet; St Louis Limestone, 250 feet. The Devonian system is represented by limestone in Marion, Ralls, Pike, Callaway, Saline, and Ste Genevieve counties, among which occur the Chouteau Limestone, 85 feet; Lithographic Limestone, 125 feet; Onondaga Limestone, 100 feet. Of the Upper Silurian series are the following formations:—Lower Helderberg, 350 feet; Niagara Group, 200 feet; Cape Girardeau Limestone, 60 feet. Prominent among the Lower Silurian formations are the Trenton Limestone, 360 feet; the Black River and Bird's Eye Limestone; and the Magnesian series. The last-named series is valuable both in a scientific and an economic sense. It covers much of the southern and south-eastern portions of the State, and in it are found vast deposits of lead, zinc, copper, cobalt, iron ores, and marble. The Archæan rocks occur below the Silurian deposits, and contain siliceous and other slates in which no fossils are found. The porphyry rocks of this formation also contain iron ores.

Coal.—The exposed coal in Missouri includes upper, middle, and lower measures. In the first are about 4 feet of coal, and the area of exposure is about 8400 square miles. The middle coal measures contain about 7 feet of coal, and cover an exposed area of about 2000 square miles. The lower measures have five workable seams, varying from 18 inches in thickness to 4½ feet, and also some thin seams of only a few inches. In 1880 556,304 bushels of bituminous coal were raised in thirty-five counties of Missouri, the value at the pit mouth being $1,060,225. $642,772 were paid in wages to 2599 persons. The Missouri coal mines are easily worked.

Iron.—The iron ores are red hæmatite, red oxide, specular iron, brown hæmatite or limonite, and clay ironstone. Manganiferous and siliceous specular ores occur in the porphyries of the Archæan rocks, and in the granites. The greatest exposure of specular iron yet discovered is Iron Mountain, the purest mass or body of iron ore known. Analysis shows it to contain from 65 to 69 per cent. of metallic iron. The ore of Shepherd Mountain is not so rich as that of Iron Mountain, but is uniform in character, free from sulphur and phosphoric acid and on the whole superior to any other yet developed in Missouri. Pilot Knob ore gives 53 to 60 per cent. metallic iron, and has few deleterious substances. It is fine-grained, light bluish grey in colour. The ore of the Scotia iron banks and Iron Ridge are much alike in appearance and character, being specular boulders imbedded in soft red hæmatite. In some of these boulders are cavities in which the ore has taken botryoidal form, and upon these peroxide of iron crystallizations are so formed that a gorgeous show of prismatic colours is presented. The above are the chief deposits of iron ores, but limonites are found mostly in the southern parts of the State. The counties of Ste Genevieve, Madison, St François, Cape Girardeau, Bollinger, Wayne, Stoddard, Washington, Reynolds, Shannon, Carter, and Ripley have the greatest exposures of these ores, although they are found in many others. The supply of iron ores is, indeed, practically inexhaustible.

Lead.—Second only to iron among the metals of Missouri is the vast deposit of lead found in the southern parts of the State. The great disseminated lead region occupies about one-half of the northern portion of Madison, and about as much of St François county. It is in the magnesian limestone that the largest quantities have been found. In Franklin county galena is found in abundance in ferruginous clay and coarse gravel. In the great mammoth mine in Washington county is a succession of caves in which millions of pounds of lead were found adhering to the sides and roofs. The central lead district of the State comprises the counties of Cole, Cooper, Moniteau, Morgan, Miller, Benton, Maries, Camden, and Osage; the southern lead region the counties of Pulaski, Laclede, Texas, Wright, Webster, Douglass, Ozark, and Christian. The western lead district includes the counties of Hickory, Dallas, Polk, St Clair, Cedar, and Dade; the south-western the counties of Jasper, Newton, Lawrence, Stone, Barry, and M'Donald. The two counties Jasper and Newton produce fully one-half of the pig lead of Missouri. The lead mines of Granby are among the best-known in the State, and millions of pounds of lead have been taken from these lands.

Copper deposits have been found in several counties, chiefly in the south-western part of the State. *Zinc* is found, in the shape of sulphuret and also silicate of zinc, in nearly all the lead mines in south-western Missouri. It has often occurred in such masses as seriously to hinder mining operations, and until very recent years, when railroad facilities have given this ore a market, it was thrown aside as worthless. It is now an important and profitable adjunct of the lead mines of Missouri. *Cobalt* and *nickel* are found at Mine La Motte and in a few other places. *Silver* is found in small quantities in lead mines in Madison county, combined with the lead.

Clays for the manufacture of ordinary brick for building purposes and for fire-brick exist in quantities beyond computation, and kaolin has been found in a few places. *Marble* of various shades and qualities abounds in Missouri, and is an important item in its mineral wealth. *Limestones* and *sandstones* suitable for building purposes are found in many parts of the State.

Agriculture.—Indian corn, wheat, oats, and tobacco are the staple products; but cotton, hemp, and flax are also raised to some extent in the southern counties. The average yield of wheat to the acre is 30 bushels, and that return is often far exceeded. No flour is of a higher quality or more in demand in foreign as well as home markets than that made from Missouri wheat. Indian corn is especially used in fattening live stock. Blue grass, timothy, red-top, and red and white clover grow luxuriantly, and favour stock-raising. In some parts of the State pasturage can be had all the year round, and the cheapness of corn makes the raising of pork, in particular, a very profitable business. All varieties of fruit can be very successfully cultivated. The more tender fruits, such as apricots, nectarines, figs, and many choice kinds of grapes, grow here as well as the more northern fruits—the apple, the pear, the plum, and the cherry. Apples and peaches do well in all parts of the State. Six native varieties of grapes are found in luxuriant growth, and many cultivated varieties have been successfully introduced. No State, not even California, can hope ultimately to rival Missouri in the production of both red and white wines. Sheep-raising has proved remunerative in the southern counties chiefly, where the mild climate, the fine grasses, and the abundance of good water are especially favourable to this branch of agricultural industry. There are in Missouri, in round numbers, 10,000,000 acres of improved and 13,000,000 of unimproved land, including 9,000,000 acres of woodland. The cash value of the farms is estimated at $90,000,000. In 1880 there were on the farms in the State 667,776 horses, 192,027 mules and asses, 9020 oxen, 661,405 cows, 1,410,507 other cattle, 1,411,298 sheep, and 4,553,123 swine. Missouri is the fourth maize-producing State of the Union; it supplies more wine than any State except California, and is a rival of Kentucky, Virginia, Tennessee, and Maryland in the culture of tobacco, which is a

staple in the rich counties in the northern central part of the State, bordering upon the Missouri river. No State raises so many mules, asses, and hogs. The production of cereals in 1880 was—corn, 202,485,723 bushels; wheat, 24,966,627 bushels; rye, 535,426 bushels; oats, 20,670,958 bushels; barley, 123,031 bushels; buckwheat, 57,640 bushels. The production of tobacco for the same year was 12,015,657 lb from 15,521 acres, valued at $600,256. Three-fourths of this amount was raised in Chariton, Marion, Randolph, Howard, Callaway, and Saline counties.

Wild Animals.—Red-deer are found in every part of the State, especially in the thinly-settled and mountainous districts. Venison, indeed, in its season, is as cheap as good beef in the markets of St Louis. Wild turkeys are numerous in the swampy and mountainous districts, and are found in all parts of the State. Prairie chickens, or pinnated grouse, are found in the prairie portion of Missouri, and are shipped in great numbers to Eastern markets. In all parts of Missouri are found the quail or Virginia partridge, thousands of barrels of which are shipped from the State each season. The rabbit, a species of hare, is so common as to be considered a pest. The grey squirrel and the red fox-squirrel are also found in large numbers all over the State. Black bass, perch, catfish, buffalo fish, suckers, and pike are the leading varieties of native fish.

Manufactures.—In 1880 Missouri had about 20,000 manufacturing establishments, in which a capital of about $125,000,000 was employed. The products of these establishments were valued at upwards of $300,000,000. The leading manufacturing counties outside of the city of St Louis are Jackson, Buchanan, St Charles, Marion, Franklin, Greene, Cape Girardeau, Platte, Boone, and Lafayette; but more than three-fourths of the manufactures are produced at St Louis, which is the fourth manufacturing city of the Union. The chief manufacture is that of flour, which employs about 900 mills, and is rapidly increasing. Twenty-four mills made in St Louis, in 1880, 2,142,949 barrels of flour, having a daily output of more than 11,000 barrels. St Louis millers and dealers sent in 1880 to Europe and South America 619,103 barrels of flour; and at the world's fairs at Paris, Vienna, and Philadelphia, Missouri flour received the first award. The iron industry, which stands second in importance, is yet only in its infancy, and St Louis seems destined to be one of the great centres of iron and steel manufacture. The amount of iron made in Missouri in 1880, in twenty-two establishments employing 3139 hands, was 125,758 tons. St Louis made the same year 102,664 tons of pig-iron, steel, and rolled iron and blooms. The yearly values of a number of other industries are estimated as follows:—meat packing, $20,000,000; lumber, $10,000,000; bags and bagging, $7,000,000; saddlery, $7,000,000; oil, $6,000,000; printing and publishing, $5,500,000; furniture, $5,000,000; carriages and waggons, $4,500,000; marble and stone, $4,000,000; tin, copper, and sheet-iron, $4,000,000; agricultural implements, $2,000,000. The manufacture of glass and glass-ware is carried on to a considerable extent, especially in St Louis. At Crystal City, on the Mississippi, 30 miles below St Louis, is a very large deposit of sand suitable for the manufacture of plate-glass, and a company has been organized and is now in successful operation, with a capital of $1,000,000.

Commerce.—The extensive commerce of Missouri centres at St Louis, between which city and the ports on the Mississippi and Missouri rivers steamboats are constantly plying. Railroad transportation has, in recent years, furnished superior and cheaper facilities for much of the trade which formerly depended upon the rivers. The trade in cotton especially has been greatly increased in Missouri since 1870 by the use of railroad transportation, which has made St Louis one of the great cotton centres of the United States. Extensive cotton presses were built in St Louis in that year, and the receipts of cotton from the more southern States has increased rapidly—from 12,264 bales in 1869-70 to 457,563 bales in 1879-80. Railroad connexions have made the interior portions of Arkansas and Texas more accessible to St Louis than to the southern ports of shipment, and the trade with the south-west, with the Indians, and with Mexico is constantly increasing. In 1870 St Louis was made by Act of Congress a port of entry to which foreign merchandise could be brought in bond. The value of the direct imports for the year ending 30th June 1882 was $1,934,342.

Population.—Missouri is divided into 114 counties. The following table gives the number of inhabitants since 1850:—

Year.	Males.	Females.	Total.	Density per square mile.
1850	357,832	324,212	682,044	14·37
1860	622,201	559,811	1,182,012	18·08
1870	896,347	824,948	1,721,295	26·34
1880	1,127,187	1,041,193	2,168,380	31·55

In 1880 the foreign-born residents numbered 211,578, or 9·7 per cent., of whom 109,974 were Germans and Scandinavians; there were also 145,046 of African descent. The early settlers of the State were French, and their descendants are still found in St [illegible] Ste Genevieve and a few other smaller towns. Many Gern[illegible] recently settled in all parts of the State, while English, Irish[illegible] and Swedes have also made Missouri their home in cons[illegible] numbers. The native American population is mostly des[illegible] from immigrants from the States of Kentucky, Tennessee, North Carolina, and Virginia. During recent years there has been a large accession to the population from the eastern and north-western States.

St Louis, the chief city of the Mississippi valley, situated upon the Mississippi river about 12 miles below the mouth of the Missouri, has a population of 350,518; Kansas City, a thriving town on the western border, situated on the banks of the Missouri, has 55,785; St Joseph, in the north-west, has 32,431; Hannibal, in the north-east, has 11,074; and Jefferson City (the State capital), in the centre, has 5271.

Education.—Missouri has a public school system of education first adopted in 1839. There are district schools, elementary and ungraded; city schools, graded, with high school courses; four normal schools, and a State university. Free public schools for white and coloured children between the ages of six and twenty years are required by law for every district in the State. Besides these public institutions supported by the State there are many private schools and colleges for both sexes. Chief among these are the St Louis University, an institution managed by the Jesuits; the College of Christian Brothers, also under the control of the Roman Catholics; and Washington University, a non-sectarian endowed school, which has property estimated at $1,000,000, and more than 1300 students. The Baptists have a college at Liberty called William Jewell College; the Congregationalists one at Springfield called Drury College; and the Methodists and Presbyterians several colleges and seminaries.

Religion.—The early settlers of Missouri were Roman Catholics, and in the river towns may be found to-day a large number of that faith. The Baptists have 88,999 members, with 1385 churches; the Methodists, 96,270 members and 918 churches; the Protestant Episcopal Church, 25,000 members and 65 church buildings; the Presbyterians, with their various branches, 34,628 members and 706 churches.

Administration.—The legislative power is vested in a body consisting of a senate and a house of representatives, which meets once in every two years, on the Wednesday after the first day of January next after the election of the members thereof. Member[illegible] of the legislature are paid a sum not to exceed $5 a day for th[illegible] first seventy days of the session, and after that not to exceed $1 [illegible] day for the remainder of the session. They are also allowed mil[illegible]age. The executive department consists of a governor, a lie[illegible]tenant-governor, a secretary of state, a State auditor, Sta[illegible] treasurer, an attorney-general, and a superintendent of publi[illegible] instruction; these are all elected by the people. The suprem[illegible] executive power is vested in the governor, who is chosen for fou[illegible] years, as also are the other members of this department. Th[illegible] governor has a qualified veto upon the acts of the legislature, an[illegible] such other powers as are common to that officer in the severa[illegible] States. The judicial power of the State is lodged in a supren[illegible] court, the St Louis court of appeals, circuit courts, crimin[illegible] courts, probate courts, and municipal courts. All judicial office[illegible] are elected by the people. Judges of the supreme court are electe[illegible] for ten years, those of the St Louis court of appeals for twelv[illegible] years, those of the circuit courts for six years. Executive an[illegible] judicial officers are liable to impeachment by the house of repre[illegible]sentatives. All impeachment cases are tried by the senate.

Every male citizen of the United States, and every male perso[illegible] of foreign birth who may have declared his intention to become [illegible] citizen of the United States, according to law, not less than on[illegible] year nor more than five years before he offers to vote, who is ove[illegible] the age of twenty-one years, is entitled to vote at all elections b[illegible] the people, if he has resided in the State one year immediatel[illegible] preceding the election at which he offers to vote, and has reside[illegible] in the county, city, or town where he shall offer to vote at leas[illegible] sixty days immediately preceding the election.

History.—On the 9th April 1682, the French voyager and discoverer La Salle took possession of the country of Louisiana in the name of the king of France. Its limits were quite indefinite, and included the present territory of Missouri (see LOUISIANA). The first settlements of Missouri were made in Ste Genevieve and at New Bourbon, but uncertainty exists as to the exact date. By some the year is fixed at 1763; by others, and by many traditions, as early as 1735. St Louis was settled by Pierre Laclede Liguest, a native of France. The site was chosen in 1763, and in February 1764 Auguste Chouteau went at the order of Liguest to the spot previously selected, and built a small village. For a long time the settlements were confined to the neighbourhood of the river. On the 31st of October 1803 the Congress of the United States passed an Act by which the president was authorized to take possession of the territory according to the treaty of Paris, and the formal transfer of Lower Louisiana was made on 20th December

1803. In 1804 Congress divided the territory into two portions. The northern part, commonly called Upper Louisiana, was taken possession of in March 1804. In June 1812 Missouri was organized as a Territory, with a governor and general assembly. The first governor (1813-1820) was William Clarke. In 1818 Missouri applied for admission to the Union as a State. Two years of bitter controversy followed, which convulsed the country and threatened the dissolution of the Union. This controversy followed a resolution introduced into Congress which had in view an anti-slavery restriction upon the admission of Missouri to the Union. This was at last settled by the adoption of the "Missouri compromise," which forbade slavery in all that portion of the Louisiana purchase lying north of 36° 30′ except in Missouri, and on 19th July 1820 Missouri was admitted to the Union. A convention to frame a constitution had already been called, and the constitution then adopted remained without material change until 1865. The first general assembly under the constitution met in St Louis in September 1820, and Alexander M'Nair was chosen governor in August. The seat of government was fixed at St Charles in 1820, and removed to Jefferson City, the present State capital, in 1826. The first census of the State was taken in 1821, when the number of inhabitants was found to be 70,647, of whom 11,254 were slaves. In the Black Hawk war in 1832, the Florida war in 1837, and the Mexican war in 1846 Missouri volunteer troops did their share of the work. In the troubles in Kansas, and the bitter discussion upon the question of slavery, Missouri was deeply involved. A strong feeling in favour of secession showed itself in many parts of the State. Governor Jackson, in his inaugural address on the 4th of January 1861, said that Missouri must stand by the slaveholding States, whatever might be their course. The election of a majority of Union men, however, as delegates to a convention called to consider the affairs of the nation, showed that public sentiment was hostile to secession, and the convention adjourned without committing the State to the secession party. United States troops were soon gathered at St Louis, and forces were also sent to Jefferson City, and to Rolla. Governor Jackson fled from the capital, and summoned all the State troops to meet him at Booneville. General Lyon defeated these troops, 17th June 1861, and soon most of the State was under the control of the United States forces. The State convention was reassembled. This body declared vacant the offices of governor, lieutenant-governor, and secretary of state, and filled them by appointment. The seats of the members of the legislature were also declared vacant. Governor Jackson soon issued a proclamation declaring the State out of the Union, and Confederate forces were assembled in large numbers in the south-western part of the State. General Lyon was killed at the battle of Wilson's Creek near Springfield, and General Fremont, commanding the department of the west, decreed martial law throughout the State. For a year matters were favourable to the Confederates, and at the opening of 1862 their troops held nearly half the State; but in February a Federal force under General Curtis drove General Price into Arkansas. He returned in 1864, and overran a large part of the State, but was finally forced to retreat, and but little further trouble arose in Missouri during the war. Missouri furnished to the United States army during the war 108,773 troops. In 1865 a new constitution was adopted by the people. In 1869 the XV. Amendment to the United States constitution was adopted by a large majority. In 1875 still another State constitution was drawn up by a convention called for that purpose, and ratified by the people, and is now the fundamental law of the State. (M. S. S.)

MISTLETOE[1] (*Viscum album*, L.), a species of *Viscum*, of the family *Loranthaceæ*. The whole genus is parasitical, and seventy-six species have been described; but only the mistletoe proper is a native of Europe. It forms an evergreen bush, about 4 feet in length, thickly crowded with (falsely) dichotomous branches and opposite leaves. The leaves are about 2 inches long, obovate-lanceolate, yellowish green; the diœcious flowers, which are small and nearly of the same colour but yellower, appear in February and March; the fruit, which when ripe is filled with a viscous semitransparent pulp (whence birdlime is derived), is almost always white, but there is said to be a variety with red fruit. The mistletoe is parasitic both on deciduous and evergreen trees and shrubs, and "it would be difficult to say on what dicotyledonous trees it does not grow" (Loudon). In England it is most abundant on the apple tree, but rarely found on the oak. The fruit is eaten by most frugivorous birds, and through their agency, particularly that of the thrush (hence missel-thrush or mistle-thrush), the plant is propagated. (The Latin proverb has it that "Turdus malum sibi cacat"; but the sowing is really effected by the bird wiping its beak, to which the seeds adhere, against the bark of the tree on which it has alighted.) The growth of the plant is slow, and its durability proportionately great, its death being determined generally by that of the tree on which it has established itself. See Loudon, *Arboretum et Fruticetum Britannicum*, vol. ii. p. 1021 (1838). The mistletoe so extensively used in England at Christmas tide is largely derived from the apple orchards of Normandy.

Pliny (*H. N.*, xvi. 92-95; xxiv. 6) has a good deal to tell about the *viscum*, a deadly parasite, though slower in its action than ivy. He distinguishes three "genera." "On the fir and larch grows what is called *stelis* in Eubœa and *hyphear* in Arcadia." Viscum, called *dryos hyphear*, is most plentiful on the esculent oak (quercus), but occurs also on the robur, *Prunus sylvestris*, and terebinth. Hyphear is useful for fattening cattle if they are hardy enough to withstand the purgative effect it produces at first; viscum is medicinally of value as an emollient, and in cases of tumour, ulcers, and the like; and he also notes it "conceptum fœminarum adjuvare si omnino secum habeant." Pliny is also our authority for the reverence in which the mistletoe when found growing on the robur was held by the Druids. The robur, he says, is their sacred tree, and whatever is found growing upon it they regard as sent from heaven and as the mark of a tree chosen by God. Such cases of parasitism are rare, and when they occur attract much attention (est autem id rarum admodum inventu et repertum magna religione petitur), particularly on the sixth (day of the) moon, with which their months and years and, after the lapse of thirty years, their "ages" begin. Calling it in their own language "all heal" (omnia sanantem), after their sacrifices and banquets have been duly prepared under the tree, they bring near two white bulls whose horns are then for the first time bound. The priest clothed with a white robe ascends the tree, cuts [the mistletoe] with a golden hook; it is caught in a white mantle. They then slay the victims, praying God to prosper His gift to them unto whom He has given it. Prepared as a draught, it is used as a cure for sterility and a remedy for poisons. The mistletoe figures also in Scandinavian legend as having furnished the material of the arrow with which Baldur (the sun-god) was slain by the blind god Höder. Most probably this story had its origin in a particular theory as to the meaning of the word mistletoe.

MITAU (the Lettish Jelgava), a town of Russia, capital of the government of Courland. It is situated 27 miles by rail to the south-west of Riga, on the right bank of the river Aa, in a fertile plain which rises only 12 feet above sea-level, and which probably has given its name to the town (*Mitte in der Aue*). At high water the plain and sometimes also the town are inundated. Mitau is surrounded by a canal occupying the place of former fortifications. Another canal was dug through the town to provide it with water; but this now receives the sewage, and water is brought in cars from a distance of 3 miles. Though so near Riga, Mitau has quite a different character. It has regular broad streets, bordered with the low pretty mansions of the German nobility who reside at the capital of Courland either to enjoy the social amusements for which Mitau is renowned or to provide education to their children. Mitau is well provided with educational institutions. A gymnasium occupies a former palace of the dukes of Courland, and has a rich library; and there are about forty other schools. The town is also the seat of a society of art and literature, of a natural history society, which has a good local museum, and of the Lettish Literary Society. The old castle of the dukes of Courland, which has witnessed so many conflicts, was destroyed by the Duke Biron, who erected in its place a spacious palace, now occupied by the governor and the courts. Mitau has 22,200 inhabitants, mainly Germans, but including also Jews (about 6000), Letts (5000), and Russians. Manufactures are few, those

[1] Greek ἰξία or ἰξός, hence Latin *viscum*, Italian *vischio* or *visco*, and French *gui*. The English word is the Anglo-Saxon *misteltan*, Icelandic *mistelteinn*, in which *tan* or *teinn* means a twig, and *mistel* may be associated either with *mist* in the sense of fog, gloom, because of the prominence of mistletoe in the dark season of the year, or with the same root in the sense of dung (from the character of the berries or the supposed mode of propagation).

of wrought-iron ware and of white-lead being the most important. The river Aa brings Mitau in connexion with the trade of Riga, small vessels carrying goods to the amount of about £150,000 a year.

Mitau is supposed to have been founded in 1266 by the grand-master Conrad Mandern. It has often changed its rulers. In 1345, when it was plundered by Lithuanians, it was already an important town. In 1561 it became the residence of the dukes of Courland. During the 17th century it was thrice taken by the Swedes. Russia annexed it with Courland in 1795. At the beginning of this century it was the residence of the count of Provence (afterwards Louis XVIII.). In 1812 it was taken by Napoleon I.

MITCHEL, ORMSBY M'KNIGHT (1810–1862), American general and writer on astronomy, was born in Union county, Kentucky, August 28, 1810. He began life as a clerk, but, obtaining an appointment to a cadetship at West Point in 1825, he graduated there in 1829, and became assistant professor of mathematics in 1831. Subsequently he was called to the bar, but forsook law to become professor of mathematics and natural philosophy at Cincinnati college. There he established an observatory, of which he became director. From 1859 to 1861 he was director of the Dudley observatory at Albany. He took part in the war as brigadier-general of volunteers, and for his skill and rapidity in seizing certain important strategic points was on April 11, 1862, made major-general. He died of yellow fever at Beaufort, South Carolina, October 30, 1862. Besides making important improvements on several astronomical instruments, Mitchel was the author of several works on astronomy, the principal of which are *The Planetary and Stellar Worlds* (1848) and *The Orbs of Heaven* (1851). See *Memoir* by Headley (1865).

MITCHELL, SIR THOMAS LIVINGSTONE (1792–1855), Australian explorer, was a son of Mitchell of Craigend, Stirlingshire, where he was born, June 16, 1792. From 1808 to the end of the Peninsular War he served in Wellington's army, and for his services received the medal and five clasps, and was raised to the rank of major. He was appointed to survey the battlefields of the Peninsula, and his map of the Lower Pyrenees is still admired. In 1827 he was appointed deputy surveyor-general, and afterwards surveyor-general, of New South Wales. He devoted himself to the exploration of Australia, making four expeditions for that purpose between 1831 and 1846. During these expeditions he discovered the Peel, the Namoi, the Gwyder, and other rivers, traced the course of the Darling and Glenelg, and was the first to penetrate into that portion of the country which he named Australia Felix. His last expedition was mainly devoted to the discovery of a route between Sydney and the Gulf of Carpentaria, and during the journey he explored the Fitzroy Downs, and discovered the Balonne, Victoria, Warrego, and other streams. In 1838, while in England, Mitchell published the narrative of his first three journeys, *Three Expeditions into the Interior of East Australia* (2 vols.). In 1839 he was knighted and made a D.C.L. of Oxford. During this visit he took with him some of the first specimens of gold and the first diamond found in the country. In 1848 the narrative of his second expedition was published in London, *Journal of an Expedition into the Interior of Tropical Australia.* In 1851 he was sent to report on the Bathurst gold-fields, and in 1853 he again visited England and patented his boomerang propeller for steamers. He died at his residence at Darling Point, Sydney, October 5, 1855.

Besides the above works, Mitchell wrote a book on *Geographical and Military Surveying* (1827), an *Australian Geography*, and a translation of the *Lusiad* of Camoens.

MITE. Mites (*Acarina*) are minute creatures which form a large division of the *Arachnida*, distinguished by the absence of any constriction between the cephalothorax and abdomen. Linnæus included all in the single genus *Acarus*. They are now divided into several families (mostly containing numerous genera), viz., *Trombidiidæ* (harvest mites), usually scarlet specks seen running on stones, grass, &c., in hot weather; *Tetranychi*, which, although not bright red, are the red spider of our green-houses, and are distinguished by feet with knobbed hairs; *Bdellidæ*, long-snouted mites with antenniform palpi; *Cheyletidæ* (fig. 1), the so-called book mites,—ferocious, predatory little beings, quite unconnected with books; *Hydrachnidæ*, freshwater mites with swimming legs, mostly beautiful creatures of brilliant colours; *Limnocaridæ*, crawling freshwater or mud mites; *Halicaridæ*, chiefly marine; *Gamasidæ*, hard-skinned brown mites often parasitic on insects, and best known by the females, and young of both sexes, found on the common dung beetle (*Geotrupes stercorarius*); *Ixodidæ*, the true ticks, not to be confounded with the sheep-tick, &c., which are wingless flies; *Oribatidæ*, beetle mites, so called from their resemblance to minute beetles (these are never parasitic; they undergo transformations almost as strange as those of insects, many of the immature forms being quaint and beautiful, see fig. 2); *Myobiadæ*, bizarre parasites of the mouse, &c., with peculiar holding claws; *Tyroglyphidæ*, the cheese mites; *Analgidæ*, found on the feathers of birds; *Sarcoptidæ*, the itch mites; *Arctisconidæ*, the water bears; *Demodicidæ*, found in the sebaceous follicles of the human nose, &c.; and *Phytoptidæ*, the gall mites, which attack the leaves of plants, making tiny gall-like excrescences.

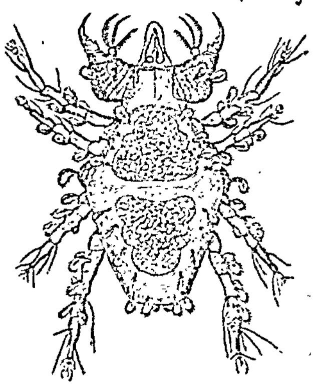


FIG. 1.—*Cheyletus flabellifer.*

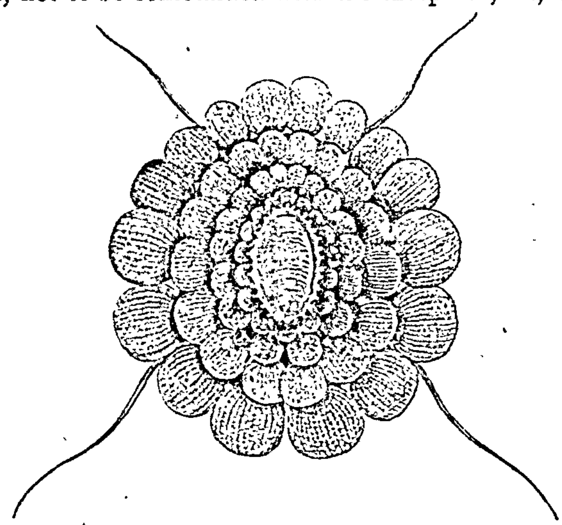


FIG. 2.—*Leiosoma palmicinctum*; nymph.

The sexes are distinct individuals; the reproduction is oviparous; the larva is almost always hexapod, though the later stages have eight legs; that answering to the pupa of insects is active, and is called the nymph. The breathing in the first-named eleven families is tracheal, the position of the stigmata varying greatly; in the last-named six families it is by the general body surface. No heart or circulation of the blood is known to exist; the alimentary canal is usually somewhat on the insect type, but with cæcal prolongations to the stomach, the reproductive organs often more on the crustacean type. There is generally a single very large nerve-ganglion above the œsophagus, sending nerve-branches to the various parts. The legs have ordinarily five to

seven joints, rarely three; the feet are usually terminated by claws or suckers, or both, sometimes by bristles. The mandibles are generally large, oftenest chelate (like a lobster's claw), sometimes style-like piercing organs, and of other forms. The maxillæ vary much: they may be piercing or crushing organs, or may coalesce to form a maxillary lip; there is usually one pair of maxillary palpi, no others. Sometimes there is a lingua, and in the *Gamasidæ* a galea. Antennæ are not found.

Mites are distributed all over the known world. They have been found in Franz-Josef's Land and Spitzbergen and in the hottest tropical regions, as well as the temperate zones. Often very similar species come from all parts. They are numerous in amber of the Tertiary epoch.

The best-known species are probably those which injure man or his works, viz., the itch mite, the cheese mite, the so-called harvest-bug, and the red spider. The dog-tick is also well known.

The itch mite (*Sarcoptes scabiei*, fig. 3) is a minute, almost circular, flattened, colourless creature, with skin covered with wavy wrinkles, and a number of triangular points arising from that of the back; legs short, the two front pairs and the fourth pair in the male terminated by suckers on long stalks, the two hind pairs in the female and third pair in the male having long bristles instead. It is parasitic on human beings: the males and young remain chiefly on the surface of the skin, but are difficult to find; the female burrows under the scarf-skin, causing the intense itching of scabies by the action of her chelate mandibles as she eats her way. A small watery pustule is raised near where the acarus has entered the skin, and others arise; the creature is not found in the pustule, but at the further end of a short tunnel which may be half an inch long. The eggs are laid in the tunnel after the acarus has passed; they hatch and multiply rapidly. The disease can be certainly cured; the usual mode is to rub the whole body with sulphur ointment, which is best done after a warm bath, allow it to remain on all night, and wash off in the morning. This treatment should be repeated once or twice at intervals of a day or two. Other applications of sulphur, as sulphurous acid, sulphur vapour baths, &c., are efficacious. All clothes which have touched the skin must be disinfected by heat. The disease is highly contagious. Most mammals have their peculiar varieties of itch mite.

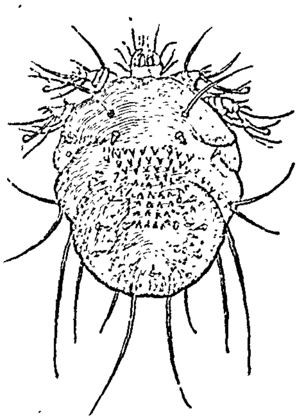


Fig. 3.—The Itch Mite (*Sarcoptes scabiei*); female. After Meguin.

The cheese mite (*Tyroglyphus siro*) is an elliptical, fat-bodied, colourless acarus with smooth skin and very long hairs. It breeds in thousands in old cheese, flour, grain, &c., and does much damage. There are numerous allied species; some belonging to the genus *Glyciphagus* are elegantly ornamented with plumes or leaf-like hairs.

The red-spider (*Tetranychus telarius*) attacks the leaves of plants or trees, and is a great pest in green-houses. It spins a slight web on the surface of the leaves, and lives in companies on the web; it is of a rusty red or brown.

The harvest bugs, thought by some writers to be a species, and by them called *Leptus autumnalis*, are simply the larvæ of several species of *Trombidium*. They are predatory, but will attach themselves temporarily to the human skin, and produce the violent itching felt on the lower parts of the legs after walking through dry grass in autumn. On inspection with a glass the creature may be seen as a minute scarlet point. A drop of benzine will probably get rid of the intruder.

The dog tick, like the harvest-bug, is not really parasitic on mammals, though it attaches itself temporarily; its ordinary food may probably be vegetable. (A. D. M.)

MITFORD, Mary Russell (1786–1855), born at Alresford, Hampshire, on the 16th of December 1786, retains an honourable place in English literature as the authoress of *Our Village*, a series of sketches of village scenes and characters unsurpassed in their kind, and after half a century of imitations as fresh as if they had been written yesterday. Washington Irving was Miss Mitford's literary model, but her work is thoroughly original and spontaneous, the free outflow of a singularly charming character. The shortest account of her life would be incomplete without a reference to the scapegrace father who was the centre of her affections, and the "only begetter" of all that is most delightful and characteristic in her writing. Dr Mitford first spent his wife's fortune in a few years; then he spent also in a few years the greater part of £20,000 which his daughter drew (in 1797, at the age of ten) as a prize in a lottery; then he lived, for most years of his life, on a small remnant of his fortune and the proceeds of his daughter's literary industry. In the little village of Three Mile Cross, near Reading, in a small cottage which Miss Mitford says was "a fine lesson in condensation," the doctor was the stay, support, and admiration of all the loafers in the neighbourhood, while his daughter, who had called herself his mamma, and treated him as her little boy from the time when she was herself a little girl, found an unfailing charm in his "friskings," and was the loving slave of all his good-humoured exactions. The father kept fresh in his daughter the keen delight in incongruities, the lively sympathy with self-willed vigorous individuality, and the womanly tolerance of its excess which inspire so many of her sketches of character. The woman who lived in close attendance on such an "awful dad," refused all holiday invitations because he could not live without her, and worked incessantly for him, except when she broke off her work to read him the sporting newspapers, evidently wrote from the heart in her bright portraits of such characters as the Talking Lady, the Talking Gentleman, Joel Brent, Jack Rapley, Tom Cordery, Lizzy, Lucy, and Harriet. Her writing has all the charm of perfectly unaffected spontaneous humour, combined with quick wit and exquisite literary skill. She died January 10, 1855.

Miss Mitford's youthful ambition was to be "the greatest English poetess," and her first publications were poems in the manner of Coleridge and Scott (*Miscellaneous Verses*, 1810, of sufficient mark to be reviewed by Scott in the *Quarterly*; *Christine*, a metrical tale, 1811; *Blanche*, 1813). Later on she essayed writing plays (*Julian*, 1823; *The Foscari*, 1826; *Dramatic Scenes*, 1827; *Rienzi*, 1828; *Charles the First*, 1828). But the prose to which she was driven by domestic necessities has rarer qualities than her verse. The first series of *Our Village* sketches appeared in 1824, a second in 1826, a third in 1828, a fourth in 1830, a fifth in 1832, and *Belford Regis*, a novel in which the neighbourhood and society of Reading were idealized, in 1835. Her *Recollections of a Literary Life* (1853) is a series of *causeries* about her favourite books. Five volumes of her *Life and Letters* were published in 1870 and 1872, showing her to have been a delightful letter-writer; two volumes of letters to her appeared in 1882.

MITHRADATES, or, as it is often wrongly spelt, Mithridates (*i.e.*, "given by the god Mithras"), was a favourite name of the Pontic kings in the third and second centuries B.C., and was also common in Persia and the neighbouring countries. The dynasty of Pontus was a Persian family, claiming descent from the Achæmenidæ, and the earliest of them known in history was satrap under the Persian empire. When that empire was destroyed Mithradates II. made himself king of Pontus; and he and his successors gradually spread their power over a great

part of Cappadocia and Paphlagonia. Several of them intermarried with the Seleucidæ and other Greek royal families, and something of the Hellenic civilization was engrafted on the native non-Hellenic character of the kingdom. The names Mithradates, Pharnaces, and Ariobarzanes, all non-Hellenic, alternate in the family. The province of Phrygia was sold in the most scandalous way by the Roman consul Aquillius to Mithradates V., who died probably in 120 B.C. He was succeeded by his son Mithradates Eupator, sixth of the name, one of those remarkable conquerors that arise from time to time in the East. He was a boy when his father died, and for seven years lived the wandering life of a hunter pursued by assassins. His courage, his wonderful bodily strength and size, his skill in the use of weapons, in riding, and in the chase, his speed of foot, his capacity for eating and drinking, and at the same time his quick and penetrating intellect, his wonderful mastery of twenty-two languages,—all these qualities are celebrated by the ancients to a degree which is almost incredible. With a surface gloss of Greek education, he united the subtlety, the superstition, and the obstinate endurance of an Oriental. He was a virtuoso, and collected curiosities and works of art; he assembled Greek men of letters round him; he gave prizes to the greatest poets and the best eaters. He spent much of his time in practising magic arts, the interpretation of dreams, and other superstitious ceremonies; and it was believed that he had so saturated his body with poisons that none could injure him. He trusted no one; he murdered his nearest relations, his mother, his sons, the sister whom he had married; to prevent his harem from falling a trophy to his enemies he murdered all his concubines, and his most faithful followers were never safe. He once disappeared from his palace, no one knew whither, and returned after some months, having wandered over all Asia Minor in disguise. Except in the pages of romance or the tales of the *Thousand and One Nights* it would be difficult to find anything to rival the account given of Mithradates by the gravest of historians. These qualities fitted him to be the opponent of Roman arms in Asia Minor, to be the champion of the East in its struggle against the destroying and yet civilizing power of the West. He resisted the Romans for eighteen years, yet we can hardly credit him with much real generalship or organizing power. He could collect masses of men and hurl them against the Roman legions; everything that boundless energy and boundless hatred could do he did; but the strength of his opposition to the Romans lay in the fact that all the dislike inspired by Rome in the worst and most cruel time of her rule was arrayed on his side.

No direct collision took place between the Romans and Mithradates for thirty-two years, though the republic took away Phrygia from him in 120 B.C., and several times thwarted his designs in Paphlagonia and Cappadocia. The rupture came about the time of the Social War. Mithradates, prompted, it is said, by envoys from the Italian allies, took advantage of the intestine struggles in Italy. War broke out in 88, on the ostensible cause of disputes about the kingdom of Bithynia; Mithradates rapidly overran Galatia, Phrygia, and Asia, defeated the Roman armies, and made a general massacre of the Romans resident in Asia. He also sent large armies into European Greece, and his generals occupied Athens. But Sulla in Greece and Fimbria in Asia defeated his armies in several battles; the Greek cities were disgusted by his severity, and in 84 B.C. he concluded peace, abandoning all his conquests, surrendering seventy ships, and paying a fine of 2000 talents. Murena invaded Pontus without any good reason in 83, but was defeated in 82. Difficulties constantly arose between the two adversaries, and in 74 a general war broke out. Mithradates defeated Cotta, one of the Roman consuls, at Chalcedon; but Lucullus worsted him in several engagements, and drove him finally in 72 B.C. to take refuge in Armenia with his son-in-law Tigranes. After two great victories in 69 and 68, Lucullus was disconcerted by mutiny among his troops and the defeat of his lieutenant Fabius (see vol. xv. p. 56). In 66 he was superseded by Pompey, who completely defeated both Mithradates and Tigranes. The former established himself in 64 at Panticapæum, and was planning new campaigns against the Romans when his own troops revolted, and, after vainly trying to poison himself, he ordered a Gallic mercenary to kill him. So perished the greatest enemy that the Romans had to encounter in Asia Minor. His body was sent to Pompey, who buried it in the royal sepulchre at Sinope.

MITHRAS was a Persian god whose worship spread over the Roman world during the 2d and 3d centuries after Christ. His name is found in the oldest records of the East Aryan races. In the Rig-Veda, Mitra, *i.e.*, the friend, and Varuna, *i.e.*, Οὐρανος, are a pair of gods regularly associated: they denote the heaven of day and the heaven of night. Mithras is therefore by origin the god of the bright heaven and of day, closely related in conception to, and yet expressly distinguished from, the sun. In the developed Old Persian religion of Zoroaster Mithras retained a place; he was not one of the greatest gods, but was first of a triad which, while less pure embodiments of the divine nature, were more easy for men to comprehend and to worship. The seventh month, which bears his name, and the sixteenth day of every month were sacred to Mithras; prayers were offered to him at sunrise, at mid-day, and at sunset. When the Persians conquered Assyria and Babylonia their religion was much affected by the worship of these more educated races. The worship of foreign deities was introduced, that of Persian deities was changed in character; and the gods were represented by images. The cultus of Mithras now became far more prominent, he was identified with the sun, and an elaborate ritual with the non-Aryan accompaniment of mysteries was established. This revolution had begun before Herodotus (i. 131) could identify Mithras with the Assyrian goddess Mylitta, and it became more thorough during the 4th century B.C.

It is in this most developed form that we know the cultus of Mithras. The god of light becomes by a ready transition, which is made in the very oldest Aryan records, the god of purity, of moral goodness, of knowledge. There goes on in the world as a whole, and in the life of each man, a continual struggle between the power of good and the power of evil; Mithras is always engaged in this contest, and his religion teaches all, men and women alike, to aid in the battle. Victory in this battle can be gained only by sacrifice and probation, and Mithras is conceived as always performing the mystic sacrifice through which the good will triumph. The human soul, which has been separated from the divine nature and has descended to earth, can reascend and attain union with God through a process of fasting and penance which is taught in the mysteries; the sacrifice which is being always offered by Mithras makes this ascent and union possible. Those who were initiated in the mysteries of Mithras had to pass through a long probation, with scourging, fasting, and ordeal by water, and were then admitted as soldiers fighting on behalf of Mithras. This was the lowest terrestrial grade, but there were still two others to attain, the Bull and the Lion, each involving further probation, before the soul could rise above the earth. It then ascended by the grades of Vulture, Ostrich, and Crow through the region of æther; and then it strove to become pure fire through the grades of Gryphon, of Perses, and of the Sun. Finally

the soul attained complete union with the divine nature through the grades of Father Eagle, of Father Falcon, and of Father of Fathers. A holy cave on a hill was the central point in the worship; and the mystic rites involved watching and fasting all night till sunrise brought the triumph of light.

The worship of Mithras became known to the Romans through the Cilician pirates captured by Pompey about 70 B.C. It gained a footing in Rome under Domitian, was regularly established by Trajan about 100 A.D., and by Commodus about 190. Finally the mysteries were prohibited and the holy cave destroyed in 378. Dedicatory inscriptions to *Deo Soli Invicto Mithræ*, and votive reliefs of Roman work, are very common. The usual representation shows Mithras in the mystic cave performing the mystic sacrifice; a young man in Oriental costume kneels with one knee on a prostrate bull, grasping the head and pulling it back with the left hand, while with the right he plunges his sword into its neck. A dog, a snake, and a scorpion drink the blood that flows from the bull; a crow sits on the rock behind Mithras; the figures of the sun and of the moon occupy the two sides of the relief.

See Lajarde, *Recherches sur le Culte de Mithras.*

MITRE. See COSTUME, vol. vi. p. 463; and HERALDRY, vol. xi. p. 711.

MITSCHERLICH, EILHARDT (1794–1863), was born January 7, 1794, at Neuende near Jever, in the grand-duchy of Oldenburg, where his father was pastor. He was educated at the gymnasium of Jever under the historian Schlosser. In 1811 he went to Heidelberg, where he devoted himself to philology, giving special attention to the Persian language. In 1813 he went to Paris, partly for study, partly with the view of obtaining permission to join a French embassy to Persia. The political events of 1814 put an end to this scheme, and Mitscherlich returned to Germany. He then set to work on a history of the Ghurides and Kara-Chitayens, manuscript materials for which he found in the university library of Göttingen, and a portion of which he published in 1815. Still anxious to visit Persia, he resolved to study medicine in order that he might enjoy that freedom of travel usually allowed in the East to physicians. He began at Göttingen with the study of chemistry, and this so completely arrested his attention that he gave up the idea of the journey to Persia and the medical profession. In 1818 he went to Berlin, where he worked in the laboratory of Professor Link. He made analyses of phosphates and phosphites, arseniates and arsenites, confirming the observations of Berzelius as to their composition. In the course of these investigations he observed that corresponding phosphates and arseniates crystallized in the same form.

This was the germ from which grew the theory of isomorphism. In order to follow out his discovery Mitscherlich set to work to learn crystallography. His teacher was a fellow student, Gustav Rose, to whose penetrating mind and profound knowledge of mineralogy have been due some of the most interesting developments and illustrations of the theory of isomorphism. Having measured the inclinations of the faces of a vast number of natural and artificial crystals, he established the principles of isomorphism very much as we now hold them.

It is right that we should remember that Mitscherlich was not the first to notice the fact that two different substances might have the same crystalline form, or that one element could partially replace another without great change of form. Romé de l'Isle in 1772 mentions mixed vitriols containing variable proportions of iron and copper, and Leblanc in 1802 showed that the crystalline form remains the same although the proportions vary both in the case of these mixed vitriols and in that of mixed alums. Vauquelin had already, in 1797, proved that alum might contain variable quantities of ammonia without any corresponding variation of crystalline form.

The authority of Haüy, who laid down as one of his principles that each compound has its own crystalline form, for a time kept these observations in the background. Further cases were, however, observed. Wollaston (1812) accurately measured the angles of the rhombohedral carbonates, and proved that the forms of these minerals, although nearly the same, are not absolutely identical. He showed that a similar close approximation to identity exists in the case of the vitriols. Fuchs in 1815 brought forward his theory of "vicarious constituents." Gay-Lussac proved that a crystal of common alum continues to grow when placed in a solution of ammonia alum, and cases of crystallized mixtures were pointed out by the French mineralogist Beudant. But notwithstanding these foreshadowings, of which we know, on the evidence of Gustav Rose, that Mitscherlich was wholly ignorant, there was at the time of which we are now speaking no trace of a theory, but merely isolated observations. The theory of isomorphism is the work of Mitscherlich. It was communicated to the Berlin Academy on December 9, 1819.

In that year Berzelius paid a visit to Berlin, and was so struck with Mitscherlich's ability that he suggested him to the minister Altenstein as the most fitting successor to Klaproth in the chair of chemistry in that university. It is not surprising that this idea was not carried out. It was only four years since Mitscherlich had begun to study chemistry; he had never lectured, nor had he published anything on the subject.

Although Altenstein did not at that time carry out the proposal of Berzelius, he was so far impressed by it that he obtained for Mitscherlich a Government grant to enable him to continue his studies under Berzelius.

In 1820 he went to Stockholm, where he worked for a year in Berzelius's laboratory. In 1822 he was appointed extraordinary and in 1825 ordinary professor in Berlin. In the course of an investigation into the slight differences discovered by Wollaston in the angles of the rhombohedra of the carbonates isomorphous with calc-spar, Mitscherlich observed that the angle in the case of calc-spar varied with the temperature. On extending his inquiry to other non-isotropic crystals he observed a similar variation, and was thus led, in 1825, to the discovery that non-isotropic crystals, when heated, expand unequally in the direction of dissimilar axes. In the following year he discovered the change, produced by change of temperature, in the direction of the optic axes of selenite. The discovery (also in 1826) that sulphur can be obtained in two absolutely distinct crystalline forms threw much light on the fact that the two minerals calc-spar and aragonite have the same composition but perfectly different forms. Other cases of this property, to which Mitscherlich gave the name of dimorphism, were arrived at not long after.

In 1833 he made a series of careful determinations of the vapour densities of a large number of volatile substances, and proved that Gay-Lussac's law as to the proportions by volume in which oxygen, nitrogen, hydrogen, and chlorine unite with one another holds generally for volatile elements, and that the simplicity of the relation of the volume of the compound to that of the component gases is also general.

In pure chemistry Mitscherlich's discoveries were mainly connected with isomorphism. Thus he obtained selenic acid in 1827, and showed the isomorphism of its salts with the sulphates, and examined with great care the manganates and permanganates, showing their isomorphism with the sulphates and with the perchlorates respectively. But he did much important work unconnected with this special

subject. We may in particular refer to his discovery of the relation of benzene to benzoic acid, of nitro-benzene, and of a considerable number of the derivatives of benzene.

In 1833 he published his *Lehrbuch der Chemie*, a student's text-book of chemistry of the most thoroughly practical and yet rigidly scientific kind, from the study of which teachers of chemistry may still derive many a valuable hint. His interest in mineralogy led him to the study of the geology of volcanic regions, and he made frequent visits to the Eifel with a view to the discovery of a theory of volcanic action. He did not, however, publish any papers on the subject, but since his death his notes have been arranged and published by Dr Roth in the *Memoirs* of the Berlin Academy (1866). In December 1861 symptoms of heart disease made their appearance, but he was able to carry on his academical work till December 1862. He died at Schöneberg near Berlin on 28th August 1863.

Mitscherlich's published papers are chiefly to be found in the *Abhandlungen* of the Berlin Academy, in *Poggendorff's Annalen*, and in the *Annales de Chimie et de Physique*. The fourth edition of the *Lehrbuch der Chemie* was published in 1844; a fifth was begun in 1855, but was not completed. (A. C. B.)

MITYLENE, or MYTILENE. See LESBOS.

MIZPAH (מִצְפָּה) and MIZPEH (מִצְפֶּה) are Hebrew words for a "place of prospect," or high commanding point. The cities of Palestine generally occupied such positions; and so in the Old Testament we find several places bearing the name of "The Mizpah" (Mizpeh). Sometimes a determining genitive is added; "The Mizpeh of Gilead" (Judg. xi. 29), "The Mizpeh of Moab" (1 Sam. xxii. 3).

(1) The most famous of these places is that in Gilead, a noted sanctuary (Judg. xi. 11; Hosea v. 1), claiming consecration from the sacrifice of Jacob (Gen. xxxi. 54) and the *maṣṣeba* or sacred stone erected by him (ver. 45). The narrative of Gen. xxxi. 45 *sq.* is somewhat obscure, and not all from one hand. We gather, however, from it that another name of "The Mizpah" was Galeed, *i.e.*, Gilead. Thus Mizpah, Mizpeh Gilead, Gilead (Hos. vi. 8), Ramath Mizpeh (*i.e.*, the height of Mizpeh, Josh. xiii. 26), and Ramoth Gilead (the heights of Gilead), or simply The Ramah (2 Kings viii. 28, 29), are almost universally taken to be one place. With this it agrees that Ramoth Gilead was a city of refuge, which points to an early sanctity. The place is prominent throughout the history. It was the seat of Jephthah (Judg. xi.), the mourning for whose daughter probably gives us a glimpse into the ancient rites of a provincial sanctuary, the residence of one of Solomon's officers (1 Kings iv. 13), and a hotly disputed frontier city in the wars between Syria and the house of Omri, before which Ahab fell (1 Kings xxii.), and in which the military revolt of Jehu was organized (2 Kings ix.). Maspha was still a strong place in the Greek period, and was taken by Judas Maccabæus (1 Mac. v. 35). Eusebius knows Ramoth as a place 15 miles west of Philadelphia or Rabbah of Ammon. It is therefore commonly identified with El-Salt, the modern capital of the Belká; but this cannot be said to be made out. (2) The Benjamite Mizpah or Mizpeh, also a sanctuary, is often named in the history of Samuel. It was a border fortress of King Asa (1 Kings xv. 22), and the residence of Gedaliah as governor of Judæa after the fall of Jerusalem (Jer. xl.). Its old sanctity was still remembered in the Maccabee times, and from 1 Mac. iii. 46 we conclude that it commanded a view of Jerusalem. The most probable identification is with the prominent hill-top of Neby Samwíl. There was (3) another Mizpeh in the low country of Judah (Josh. xv. 38), and (4) a land or valley of Mizpeh (Josh. xi. 3, 8) under Mount Hermon.

MNEMONICS, or artificial helps to the memory, have been employed in a more or less systematic form from a very early period. Mnemonics (τὸ μνημονικόν, sc. τέχνημα or παράγγελμα) were much cultivated by Greek sophists and philosophers, and are repeatedly referred to by Plato and Aristotle. In later times the invention was ascribed to the poet Simonides,[1] perhaps for no other reason than that the strength of his memory was famous. Cicero, who attaches considerable importance to the art, but more to the principle of order as the best help to memory, speaks of Carneades (or perhaps Charmades) of Athens and Metrodorus of Scepsis as distinguished examples of the use of well-ordered images to aid the memory. The latter is said by Pliny to have carried the art so far *ut nihil non iisdem verbis redderet auditum*. The Romans valued such helps as giving facility in public speaking. The method used is described by the author of *Rhet. ad Heren.*, iii. 16-24; see also Quintilian (*Inst. Or.*, x. 1, 2), whose account is, however, somewhat incomplete and obscure. In his time the art had almost ceased to be practised. The Greek and Roman system of mnemonics was founded on the use of mental places and signs or pictures. The thing to be remembered was localized in the imagination, and associated with a symbol which concretely represented what it was desired to retain in the memory, special care being taken that the symbols should be as vivid, pleasing, and impressive as possible. The most usual method was to choose a large house, of which the apartments, walls, windows, statues, furniture, &c., were severally associated with certain names, phrases, events, or ideas, by means of symbolic pictures; and to recall these it was only necessary to search over the apartments of the house, till the particular place was discovered where they had been deposited by the imagination. As the things to be remembered increased, new houses could be built, each set apart to a certain class of ideas or events, and these houses were again constructed into a mnemonic town. In accordance with this system, if it were desired to fix an historic date in the memory, it was localized in an imaginary town divided into a certain number of districts, each with ten houses, each house with ten rooms, and each room with a hundred quadrates or memory-places, partly on the floor, partly on the four walls, partly on the roof. Thus, if it were desired to fix in the memory the date of the invention of printing (1436), an imaginary book, or some other symbol of printing, would be placed in the thirty-sixth quadrate or memory-place of the fourth room of the first house of the historic district of the town. The success of the method depended largely on the power of the imagination to give the different houses, rooms, &c., characteristic varieties of aspect, and we may suppose that it was the effort to frame suitable images and places, giving an adventitious interest to dry details, that constituted the real advantage of the system. Except that the rules of mnemonics are referred to by Martianus Capella, nothing further is known regarding the practice of the art until the 13th century, when the system of the Romans was revived and a good many treatises were published on the subject. Among the voluminous writings of Roger Bacon is a tractate *De Arte Memorativa*, which exists in MS. at Oxford. Raymond Lully devoted special attention to mnemonics in connexion with his *ars generalis*. The first important modification of the method of the Romans was that invented by Conrad Celtes, a German poet, who, in his *Epitoma in utramque Ciceronis rhetoricam cum arte memorativa nova* (1492), instead of places made use of the letters of the alphabet. About the end of the 15th century Petrus de Ravenna awakened such astonishment in Italy by his mnemonic feats that he was believed by many to be a necromancer. His *Phœnix Artis Memoriæ*, published at Venice in 1491 in four volumes, went through as many as nine editions, the seventh appearing at Cologne in 1608. An impression equally great was produced about the end of the 16th century by Lambert Schenkel, who taught mnemonics in France, Italy, and Germany, and, although he was denounced as a sorcerer by the university of Louvain, published in 1593 his tractate *De Memoria* at Douai with the sanction of that celebrated theological faculty. The most complete account of his system is given in two works by his pupil Martin Sommer, published at Venice in 1619. Giordano Bruno, in connexion

[1] Pliny, *H. N.*, vii. 24. Cicero, *De Or.*, ii. 86, mentions this belief without committing himself to it.

with his exposition of the *ars generalis* of Lully, included a *memoria technica* in his treatise *De Umbris Idearum.*

About the middle of the 17th century Winckelmann made known what he called the "most fertile secret" in mnemonics, namely the use of letters with figures so as to express numbers by words; and the philosopher Leibnitz adopted an alphabet very similar to that of Winckelmann in connexion with his scheme for a form of writing common to all languages. Winckelmann's method was modified and supplemented in regard to many details by Richard Grey, who published a *Memoria Technica* in 1730. The principal part of Grey's method is briefly this: "To remember anything in history, chronology, geography, &c., a word is formed, the beginning whereof being the first syllable or syllables of the thing sought, does, by frequent repetition, of course draw after it the latter part, which is so contrived as to give the answer. Thus, in history, the Deluge happened in the year before Christ two thousand three hundred forty-eight; this is signified by the word Del*etok*, Del standing for Deluge and *etok* for 2348." To assist in retaining the mnemonical words in the memory they were formed into memorial lines. The vowel or consonant which Grey connected with a particular figure was chosen arbitrarily; but in 1806 Feinaigle, a monk from Salem near Constance, began in Paris to expound a system of mnemonics, one feature of which was to represent the numerical figures by letters chosen on account of some similarity to the figure to be represented or some accidental connexion with it. This alphabet was supplemented by a complicated system of localities and signs, with the aim of expressing, by a more vivid and impressive symbol, ideas which for want of this are apt to pass from the memory, and of establishing between ideas of the same group an intimate relation, so that the mention of the one would suggest the other. Feinaigle, who published a *Notice sur la mnémonique* at Paris in 1806, came to England in 1811, and in the following year published *The New Art of Memory.* A simplified form of Feinaigle's method was published in 1823 by Aimé Paris, and the use of symbolic pictures was revived in connexion with the latter by a Pole, Jazwinsky, of whose system an account was published by J. Bem, under the title *Exposé Général de la Méthode Mnémonique Polonaise, perfectionnée à Paris*, Paris, 1839. Various other modifications of the systems of Feinaigle and Aimé Paris were advocated by subsequent mnemonists, among them being the Phrenotyping or Brain-Printing method of Beniowsky, the Phreno-Mnemotechny of Gouraud, and the Mnemotechnik of Carl Otto, a Dane. The more complicated mnemonic systems have fallen almost into complete disuse; but methods founded chiefly on the laws of association have been taught with some success in Germany by, among others, Kothe, who is the author of *Lehrbuch der Mnemonik*, and *Katechismus der Gedächtnisskunst*, both of which have gone through several editions; and in England by Dr. Edward Pick, whose *Memory and the Rational Means of Improving it* has also obtained a wide circulation. In certain cases mnemonical devices may be found of considerable service; but all systems which have aimed at completeness have been found rather to puzzle than aid the memory. The fullest history of mnemonics is that given by J. C. F. von Aretin in his *Systematische Anleitung zur Theorie und Praxis der Mnemonik*, 1810.

MOA. See DINORNIS.

MOAB. Moab and Ammon (children of Lot) constitute along with Edom and Israel (children of Isaac) that group of four Hebrew peoples which in early antiquity had issued from the Syro-Arabian wilderness, and settled on the border of the cultivated country eastward of the great depression which extends from the Gulf of Elath to the Dead Sea, and up the valley of the Jordan. According to the book of Genesis, they had come out of Mesopotamia, and so were precursors of the larger wave which followed from the same quarter, forming the most southern outpost of the Aramæan immigration into the lands of Canaan and Heth. Whether the Hebrews were originally Aramæans is questionable, but it is certain that, like the Aramæans, they were distinct from the Canaanites, whose conquerors they were. Such was the relation of the old and new inhabitants, not only in Western Palestine after the Israelite occupation, but also, and from a much earlier period, in Eastern Palestine, where the aborigines were Amorites—that is, Canaanites—and where the Bne Ammon and Moab and the Bne Isaac successively settled in their lands. The old population did not disappear before the conquerors, but continued to subsist among them. In a considerable district—namely, in Gilead—the Amorites even remained unsubdued, and thus formed a gap, only imperfectly filled up by the Bne Ammon, between the Hebrew line of immigration on the south and the Aramæan line more to the north,—a gap which did not begin to close until the historical period. From this district they even endeavoured, and with some success, as will be afterwards seen, to recover the territory which had been taken from them in the south. But where they were the subjects of the Hebrews they constituted the basis of the population, the mainstock of the working and trading classes. The extent of their influence over the conquerors may be judged from the fact that it was their speech which gained the upper hand. The Moabites, and doubtless also the Ammonites and Edomites, spoke the language of Canaan as well as the Israelites. They must have learned it from the Canaanites in the land eastward of Jordan, prior to the period at which Jacob immigrated to and returned from Egypt. Our knowledge is extremely imperfect as regards other departments of the Canaanite influence; but in religion it has left a noticeable trace in the cultus of Baal-Peor, which was carried on in Moabite territory, but was certainly of Canaanite origin.

The assumption that the change of language was first brought about by the Israelites in the land which is called by preference that of Canaan, is rendered untenable by the fact that the Moabites also spoke Canaanitish. It is vain to urge against the identity of Hebrew and Canaanitish the distinction between Phœnician and Hebrew; for doubtless similar distinctions existed between the dialect of the Phœnician coast towns and that of the Hivites, Amorites, and Canaanites generally, whose language the Hebrews borrowed. That the Aramæans of Damascus, who also were compelled to mingle with the Hethites in the country of which they had taken possession, nevertheless retained their original tongue is to be explained by the circumstance that they continued to maintain direct relations with the mother-country of Mesopotamia, and moreover had greater internal cohesion. The designation Amorites, usually given in the Old Testament to the original inhabitants of Eastern Palestine, is substantially synonymous with that of Canaanites, although not quite so comprehensive. The Palestine of the Pre-Israelitic period, which in the Pentateuch is called the Land of Canaan, figures in Amos as the Land of the Amorites. While, however, the former name is bestowed chiefly upon that portion of the earlier population which had remained unconquered, the latter is given to the portion against which the Israelites first directed their attack and in whose territory they settled. This took place in the mountain district, first to the east and afterwards to the west of Jordan. For this reason the Amorites, as contrasted with the Canaanites of the cities of the level country, are a highland race, like the Hebrews themselves, but belong exclusively to the past. In the time of the Biblical narrators, the Canaanites are still living here and there in the land, but the Amorites have once lived where the Israelites now are. This explains the fact that, while in ordinary peaceful circumstances the Canaanites are named as the old inhabitants, the Amorites are immediately substituted for them wherever war and conquest are spoken of. Sihon and Og, with whom Moses does battle, are kings of the Amorites; in like manner it is with the twelve kings of the Amorites that Joshua has to deal westward of the Jordan. The Amorites as an extinct race of course assume a half-mythical character, and are represented as giants, tall as cedars and strong as oaks.

Just as Israel was the people of Jehovah, and Ammon the people of Milcom, Moab was the people of Chemosh (כְּמוֹשׁ, Num. xxi. 29). The kingship of Chemosh was regarded as thoroughly national and political in its character, but did not on that account exclude the institution of a human king, which existed in Moab much earlier than in Israel; in the time of Moses the Moabites had a king, and the institution was even then an old one. The capitals of the kingdom were Ar-Moab and Kir-Moab, south from the Arnon; these were not, however, the constant residences of the kings, who continued to live in their native places, as, for example, Mesha in Dibon. Doubtless there were changes of dynasty, and traces exist of a powerful aristocracy (Ariele Moab; 2 Sam. xxiii. 20).

The land of the Moabites, the Balḳá, is bounded northward and southward by Mount Gilead and Wadi 'l-Ahsá, westward and eastward by the Dead Sea and the Wilderness; it is divided into two portions by the deep bed of the Arnon, that to the north being the more level (Mishôr), and that to the south being more broken up, and constituting the proper stronghold of the nation. The soil is peculiarly adapted for sheep-farming (2 Kings iii.) and the culture of the vine (Isa. xvi.).[1]

The historical importance of the Moabites lies wholly in their contact with Israel, and we have no knowledge of them apart from this. After the Israelites had quitted Egypt and passed a nomadic life for about a generation in the neighbourhood of Kadesh, they migrated thence, still under the leadership of Moses, into northern Moab, dispossessing the Amorites, who had made themselves masters of that district. The interval from Kadesh to the Arnon could be passed only by a good understanding with Edom, Moab, and Ammon,—a proof that the ethnical relationships, which at a later period were expressed only in legend, were at that time still living and practical. In all probability the Moabites called the Israelites to their aid; they were not as yet aware that this little pastoral people was destined one day to become to them a greater danger than the Canaanites by whom they were threatened at the moment.[2]

As the story of Balaam indicates, the Moabites would willingly have been rid of their cousins after their service had been rendered, but were unable to prevent them from settling in the land of Sihon. The migration of the tribes of Israel into Western Palestine, however, and the dissolution of their warlike confederation soon afterwards made a restoration of the old frontiers possible. If King Eglon took tribute of Benjamin at Jericho, the territory between Arnon and Jordan must also have been subject to him, and Reuben must even then have lost his land, or at least his liberty. It would appear that the Moabites next extended their attacks to Mount Gilead, giving their support to the Ammonites, who, during the period of the judges, were its leading assailants. So close was the connexion between Moab and Ammon that the boundary between them vanishes for the narrators (Judges xi.).

Gilead was delivered from the Ammonites by Saul, who at the same time waged a successful war against Moab; the fact is lightly touched upon in 1 Sam. xiv. 47, as if this were a matter of course. The establishment of the monarchy necessarily involved Israel in feuds with its neighbours and kin. The Moabites being the enemies of the Israelite kingdom, David naturally sent his people for shelter thither when he had broken with Saul; the incident is precisely analogous to what happened when he himself at a later period took refuge from Saul's persecution in Philistine territory, and needs no explanation from the book of Ruth. As soon as he ceased to be the king's enemy by himself becoming king, his relations with Moab became precisely those of his predecessor. The war in which apparently casual circumstances involved him with Hanun ben Nahash of Ammon really arose out of larger causes, and thus spread to Moab and Edom as well. The end of it was that all the three Hebrew nationalities were incorporated with the kingdom of Israel; the youngest brother eclipsed and subdued his seniors, as Balaam had foreseen. Through the work of Saul and David the political system of Palestine was altogether changed: the smaller peoples were no longer a match for Israel, which established a decisive preponderance, and transformed what had hitherto been jealousy on the part of Moab and Ammon as well as of Edom into bitter hatred; this hatred did not cease even after nothing but a religious shadow remained of what had once been the political supremacy of the people of Jehovah.

The struggle with Ammon which David began ultimately assumed larger dimensions, and brought the Aramæans also into the field against him. He was successful, indeed, against them also, and destroyed their most powerful kingdom; but after his death they recovered themselves, and pressed steadily on from the borders of the wilderness towards the sea; at their head were those kings of Damascus who had established themselves on the ruins of Zoba. In presence of these enemies the already fading distinction between the ruling and the subject nationality within the kingdom of Israel now completely disappeared; and even towards the Canaanites outside the relations of the kings became friendly. It is in one instance expressly stated that the common danger threatening from the East had to do with this (2 Sam. viii. 9 *sqq.*). But, conversely, it was natural that Ammon and Moab should make common cause with the Aramæans; such an attitude was suggested by geographical position and old connexions, but above all by their helpless fury against Israel. Both nationalities must have succeeded in emancipating themselves very soon after David's death, and only now and then was some strong king of Israel able again to impose the yoke for a time, not upon the Ammonites indeed, but upon Moab. The first to do so was Omri, who garrisoned a number of their towns and compelled the king to acknowledge Israel's suzerainty by a yearly tribute of sheep,—a state of matters which continued until the death of Ahab ben Omri. But when that brave king fell in battle with the Aramæans at Ramoth Gilead (about 850 B.C.), Mesha of Dibon, then the ruler of Moab, seized the favourable opportunity to make himself and his people independent. In his famous inscription he tells how, through the wrath of Chemosh, the land had fallen into the enemy's power and endured forty years of slavery, and how by the grace of Chemosh the yoke is now broken and the Israelites ignominiously driven off. In

[1] There does not seem to have been any difference in this respect between the northern and southern portions; instead of Heshbon, Sibmah, and Jaezer (Isa. xvi.), the poet Hátim of Tayyi, a little before Mohammed, names Maáb and Zoar as the chief wine centres (Yáḳút, iv. 377, 19).

[2] The facts as a whole are indubitable; it cannot be an invention that the Israelites settled first in Kadesh, then in northern Moab, and thence passed into Palestine proper. The only doubtful point is whether the song in Num. xxi. 27 *sqq.* is contemporary evidence of these events. It is certainly not a forgery, but it is a question whether it really refers to the destruction of the kingdom of the Amorites at Heshbon. This reference rests entirely upon the words למלך אמרי סיחן, which might very well be omitted as a mere gloss, in which case the song would naturally be understood as directed against the Moabites themselves; it is in this last sense that it is taken by the author of Jer. xlviii. (Comp. E. Meyer in Stade's *Zeitschr. f. ATliche Wissensch.*, 1881, p. 129 *sqq.*) As Israel got the better of the Amorites on the plain of Moab, so did Hadad king of the Edomites vanquish the Midianites on the "field" of Moab (Gen. xxxvi. 35); this took place in Gideon's time, as is borne out by the fact that between Hadad and the downfall of the ancient Edomite monarchy, *i.e.* to the period of David, there were four reigning princes. Confused recollections of a former settlement of the Midianites in northern Moab are seen in Num. xxii. 4, 7; xxv. 18.

the Bible we find only the curt statement that Moab rebelled against Israel after the death of Ahab (2 Kings i.); on the other hand, there is a full narrative of a later attempt on the part of Joram ben Ahab to bring Mesha again into subjection—an attempt which promised very well at first, but ultimately failed completely. Joram's invasion took place not from the north but (probably very unexpectedly to the enemy) from the frontier of Edom over the Wadi 'l-Aḥsá; he marched through Judah and Edom, and the kings of those countries served as auxiliaries. He defeated a Moabite army on the frontier, penetrated into the country and laid it waste; he laid siege to the fortress of Kir-Moab so closely as to reduce it to great straits. But these straits seem to have filled the besieged with a desperate courage, for the fortunes of war suddenly changed. The Israelites were compelled to retire homeward, a great wrath (of Jehovah) having come upon them, that is, a severe disaster having befallen them, which is not described, but, from the nature of the case, must have been a sudden surprise and defeat by the enemy.[1]

As the Moabites owed their liberation from Israelite supremacy to the battle of Ramah—that is, to the Aramæans—we accordingly find them (as well as the Ammonites) afterwards always seconding the Aramæans in continual border warfare against Gilead, in which they took cruel revenge on the Israelites. With what bitterness the latter in consequence were wont to speak of their hostile kinsfolk can be gathered from Gen. xix. 30 *sqq.*—the one trace of open malice in the story of the patriarchs, and all the more striking as it occurs in a narrative of which Lot is the hero and saint, which therefore in its present form is of Moabite origin, although perhaps it has a still older Canaanite nucleus. Of these border wars we learn but little, although from casual notices it can be seen (2 Kings xiii. 20; Amos i. 13; comp. 2 Kings v. 2) that they were long kept up, although not quite uninterruptedly. But when at length the danger from the Aramæans was removed for Israel by the intervention of the Assyrians, the hour of Moab's subjection also came; Jeroboam II. extended his frontier over the eastern territory, as far as to the brook of the willows (Wadi 'l-Aḥsá). (Perhaps the song of Num. xxi. 27 *sqq.* has reference to these events.) A vivid picture of the confusion and anguish then prevalent in Moab has been preserved to us in the ancient prophecy of Isa. xv., xvi., which indeed would have greater historical value if we were able to tell precisely what in it depicts the present, and what is prediction of the future.[2]

This utterance of an older prophet was repeated some decennia later by the prophet Isaiah, with the addition of a clause adapting it to his time, to the effect that the Assyrians would carry out in all its fulness the hitherto imperfectly-executed threat. The Assyrians actually subjugated the Moabites, as well as the other small peoples of that region; but the blow was apparently not so grave as Isaiah had predicted. They lay more out of the way than their western neighbours, and perhaps their resistance to the scourge of God was not so obstinate as to demand the sharpest measures. What made it all the easier for them to reconcile themselves to the new situation was the fact that the Israelites suffered much more severely than they. From these their deadly enemies they were henceforth for ever free. They did not on that account, however, give up their old hatred, but merely transferred it from Israel to Judah. The political annihilation of the nation only intensified in Jerusalem the belief in its religious prerogative, and against this belief the hostility of neighbours was aroused more keenly than ever. The deepest offence at the religious exclusiveness of the people of Judæa, which then first began to manifest itself, was, as is easily understood, taken by their nearest relatives, Edom and Moab. They gave terrible expression to their feelings when the Chaldæans urged them on like uncaged beasts of prey against the rebellious Jews; and they joined loudly in the general chorus of malignant joy which was raised over the burning of the temple and the ruin of the holy city.[3]

"Because Moab saith: Behold the house of Judah is like all the other nations, therefore do I open his land to the Bne Kedem," says the prophet Ezekiel (xxv. 8 *sqq.*). His threat against the Moabites as well as against the Edomites and Ammonites is that they shall fall before the approach of the desert tribes. Probably in his day the tide of Arabian invasion was already slowly rising, and of course it had first to overtake the lands situated on the desert border. At all events the Arab immigration into this quarter began at an earlier date than is usually supposed; it continued for centuries, and was so gradual that the previously-introduced Aramæizing process could quietly go on alongside of it. The Edomites gave way before the pressure of the land-hungry nomads, and settled in the desolate country of Judah; the children of Lot, on the other hand, appear to have amalgamated with them,—the Ammonites maintaining their individuality longer than the Moabites, who soon entirely disappeared.

Israel and Moab had a common origin, and their early history was similar. The people of Jehovah on the one hand, the people of Chemosh on the other, had the same idea of the Godhead as head of the nation, and a like patriotism derived from religious belief,—a patriotism capable of extraordinary efforts, and which has had no parallel in the West either in ancient or in modern times. The mechanism of the theocracy also had much that was common to both nations; in both the king figures as the deity's representative, priests and prophets as the organs through whom he makes his communications. But, with all this similarity, how different were the ultimate fates of the two! The history of the one loses itself obscurely and fruitlessly in the sand; that of the other issues in eternity. One reason for the difference (which, strangely enough, seems to have been felt not by the Israelites alone but by the Moabites also) is obvious. Israel received no gentle treatment at the hands of the world; it had to carry on a continual conflict with foreign influences and hostile

[1] The narrative of Mesha in his inscription has, strange to say, not unfrequently been regarded as parallel with 2 Kings iii., and the conclusion been drawn that the Biblical narrative completely inverts the true state of the case,—it is difficult to see for what motives, for there is no braggadocio in 2 Kings iii. But it is perfectly clear that the narrative of 2 Kings iii. presupposes the revolt of Mesha as an old affair; while, *on the other hand*, Mesha's story on the stele in the Louvre is a narrative of this very revolt and its immediate consequences; it is accordingly to be regarded as parallel with 2 Kings i. 1. Elisha's miracle in Wadi 'l-Aḥsá (2 Kings iii. 16) is explained by the locality; Aḥsá means a sandy ground with moist subsoil, where, by digging trenches, water is always obtainable. The (probably compulsory) participation of the king of Edom in Joram's expedition against Moab may perhaps be brought into connexion with the fact that the Moabites burned to lime the bones of a king of Edom (Amos ii. 1).

[2] In Isa. xv. xvi. it is presupposed that the attack upon Moab has been made from the north, at a time when Judah is a comparatively powerful kingdom, exercising sovereignty over Edom also, and in a position to afford shelter to the fugitive Moabites, thus not being itself at war with them. These marks taken together can only apply to the period of Jeroboam II. and Uzziah. Hitzig will have it that Jonah ben Amittai wrote Isa. xv. xvi.; but according to 2 Kings xiv. 25 that prophet preached prosperity to Jeroboam, and not disaster to the Moabites.

[3] Zeph. ii. 8 *sq.*; 2 Kings xxiv. 2, and Jer. xii. 9 *sqq.*; Ezek. xxv. 8 *sqq.* It need hardly be said that the Moabites shared the fate of all the Palestinian peoples when supremacy passed from the Assyrians to the Chaldæans, and that, notwithstanding their hatred of the Jews, they had no difficulty in seeking alliances with them, when occasions arose on which they could be made useful (Jer. xxvii. 3).

powers; and this perpetual struggle with gods and men was not profitless, although the external catastrophe was inevitable. Moab meantime remained settled on his lees, and was not emptied from vessel to vessel (Jer. xlviii. 11), and corruption and decay were the result. This explanation, however, does not carry us far, for other peoples with fortunes as rude as those of Israel have yet failed to attain historical importance, but have simply disappeared. The service the prophets rendered at a critical time, by raising the faith of Israel from the temporal to the eternal sphere, has already been spoken of in the article ISRAEL.

Sources.—The Old Testament (Ruth and Chronicles, however, being of no historical worth in this connexion), and the inscription of Mesha, on the stone of Dibon, discovered in 1868, and now in the Louvre. The Berlin *Moabitica* are valueless,—Schlottmann himself, the unshaken champion of their genuineness, conceding that they are mere scribbling, and do not even form words, much less sentences. The literature of the subject is to be found in the commentaries on the Old Testament books, and in those on the inscription of Mesha. (J. WE.)

MOʻALLAKÁT. *Al-Moʻallakát* is the title of a group of seven longish Arabic poems, which have come down to us from the time before Islam. The name signifies "the suspended" (pl.), the traditional explanation being that these poems were hung up by the Arabs on or in the Kaʻba at Mecca. The oldest passage known to the writer where this is stated occurs in the *ʻIkd* of the Spanish Arab, Ibn ʻAbd-Rabbih (A.D. 861-940), Búlák ed. vol. iii. p. 116 *sq.* We read there: "The Arabs had such an interest in poetry, and valued it so highly, that they took seven long pieces selected from the ancient poetry, wrote them in gold on rolls (?) of Coptic cloth, and hung them up (*ʻallakat*) on the curtains which covered the Kaʻba. Hence we speak of 'the golden poem of Amraalkais,' 'the golden poem of Zohair.' The number of the golden poems is seven; they are also called 'the suspended' (*al-Moʻallakát*)." Similar statements are frequent in later Arabic works. But against this we have the testimony of a contemporary of Ibn ʻAbd-Rabbih, the grammarian Naḥḥás (*ob.* A.D. 949), who says in his commentary on the Moʻallakát: "As for the assertion that they were hung up in [*sic*] the Kaʻba, it is not known to any of those who have handed down ancient poems."[1] This cautious scholar is unquestionably right in rejecting a story so utterly unauthenticated. The customs of the Arabs before Mohammed are pretty accurately known to us; we have also a mass of information about the affairs of Mecca at the time when the Prophet arose; but no trace of this or anything like it is found in really good and ancient authorities. We hear, indeed, of a Meccan hanging up a spoil of battle on the Kaʻba (Ibn Hishám, ed. Wüstenfeld, p. 431). Less credible is the story of an important document being deposited in that sanctuary, for this looks like an instance of later usages being transferred to pre-Islamic times. But at all events this is quite a different thing from the hanging up of poetical manuscripts. To account for the disappearance of the Moʻallakát from the Kaʻba we are told, in a passage of late origin (De Sacy, *Chrestom.*, ii. 480), that they were taken down at the capture of Mecca by the Prophet. But in that case we should expect some hint of the occurrence in the circumstantial biographies of the Prophet, and in the works on the history of Mecca; and we find no such thing. That long poems were *written* at all at that remote period is improbable in the extreme. All that we know of the diffusion of Arabic poetry, even up to a time when the art of writing had become far more general than it was before the spread of Islam, points exclusively to *oral* tradition. Moreover, it is quite inconceivable that there should have been either a guild or a private individual of such acknowledged taste, or of such influence, as to bring about a consensus of opinion in favour of certain poems. Think of the mortal offence which the canonization of one poet must have given to his rivals and their tribes! It was quite another thing for an individual to give his own private estimate of the respective merits of two poets who had appealed to him as umpire; or for a number of poets to appear at large gatherings, such as the fair of ʻOkáẓ, as candidates for the place of honour in the estimation of the throng which listened to their recitations. In short, this legend, so often retailed by later Arabs, and still more frequently by Europeans, must be entirely rejected.[2] The story is a pure fabrication based on the name "suspended." The word was taken in its literal sense; and as these poems were undoubtedly prized above all others in after times, the same opinion was attributed to "the [ancient] Arabs," who were supposed to have given effect to their verdict in the way already described. A somewhat simpler version, also given by Naḥḥás in the passage already cited, is as follows: "Most of the Arabs were accustomed to meet at ʻOkáẓ and recite verses; then if the king was pleased with any poem, he said, 'Hang it up, and preserve it among my treasures.'" But, not to mention other difficulties, there was no king of all the Arabs; and it is hardly probable that any Arabian king attended the fair at ʻOkáẓ. The story that the poems were written in gold has evidently originated in the name "the golden poems" (literally "the gilded"), a figurative expression for excellence. We must interpret the designation "suspended" on the same principle. In all probability it means those (poems) which have been raised, on account of their value, to a specially honourable position. Another derivative of the same root is *ʻilk*, "precious thing."

The selection of these seven poems can scarcely have been the work of the ancient Arabs at all. It is much more likely that we owe it to some connoisseur of a later date. Now Naḥḥás says expressly in the same passage: "The true view of the matter is this: when Ḥammád arráwiya (Ḥammád the Rhapsodist) saw how little men cared for poetry, he collected these seven pieces, urged people to study them, and said to them: 'These are the [poems] of renown.'" And this agrees with all our other information. Ḥammád (who lived in the first three quarters of the 8th century A.D.) was perhaps of all men the one who knew most Arabic poetry by heart. The recitation of poems was his profession. To such a rhapsodist the task of selection is in every way appropriate; and it may be assumed that he is responsible also for the somewhat fantastic title of "the suspended."

The collection of Ḥammád appears to have consisted of the same seven poems which are found in our modern editions, composed respectively by Amraalkais, Ṭarafa, Zohair, Labíd, ʻAntara, ʻAmr ibn Kolthúm, and Ḥárith ibn Ḥilliza. These are enumerated both by Ibn ʻAbd-Rabbih, and, on the authority of the older philologists, by Naḥḥás; and all subsequent commentators seem to follow them. We have, however, evidence of the existence, at a very early period, of a slightly different arrangement. Two of the foremost authorities in Arabic poetry are Abú ʻObaida and Mofaḍḍal,—men who for care and accuracy in preserving the genuine text were far ahead of their much older contemporary Ḥammád. Both of these inserted a poem by Nábigha and one by Aʻshá in place of those of ʻAntara and Ḥárith;[3] and, if our informant has expressed

[1] Ernst Frenkel, *An-Naḥḥás' Commentar zur Muʻallaqa des Imruul-Qaʻis* (Halle, 1876), p. viii.

[2] Doubts had already been expressed by various scholars, when Hengstenberg—rigid conservative as he was in theology—openly challenged it: and since then it has been controverted at length in Nöldeke's *Beiträge zur Kenntniss der Poesie der alten Araber* (Hanover, 1864), p. xvii. *sqq.* Our highest authority on Arabic poetry, Professor Ahlwardt, concurs in this conclusion; see his *Bemerkungen über die Aechtheit der alten arabischen Gedichte* (1872), p. 25 *sq.*

[3] The passage is cited by Nöldeke, *Beiträge*, p. xx. *sq.*

himself correctly, they also called this modified collection *Mo'allakát.* Mofaddal employs, besides, the names "the seven long [poems]" and "the necklaces." This last became afterwards a common title for the seven poems. The comparison of songs to strings of pearls is a very apt one, from the nature of the Arabic poem, composed as it is of separate loosely-connected parts. Hence it became so popular that even in ordinary prose to speak in rhythmical form is called simply *nazm*, "to string pearls." Mofaddal expressly opposes the view of those who did not acknowledge the pre-eminence of the seven poets selected by him. This appears to be an attack on Hammád for including in his collection the works of two men who for poetic fame could certainly never enter the lists with Nábigha and A'shá. It is *prima facie* more likely that a later writer should have replaced the less famous poets by those who were universally placed in the first rank, than *vice versa.* Perhaps another fact is of some importance here. Hammád, a Persian by descent, was a client of the Arab tribe, Bakr *ibn* Wáil. In the heathen period this tribe was much at war with the closely-related tribe Taghlib. Now of all Arabic poems none was more famous than that in which 'Amr ibn Kolthúm celebrates in glowing terms the praises of his tribe Taghlib. If, therefore, Hammád's collection embraced this poem, it was very natural for him to gratify his patrons the Bakrites by placing alongside of it that of Hárith—a Bakrite and contemporary of 'Amr—where he extols his own tribe and assails the Taghlibites with bitter scorn. Such considerations did not affect Abú 'Obaida and Mofaddal.

The authority of these men has so far prevailed that the poems of their favourites Nábigha and A'shá often appear in the manuscripts, not indeed instead of those of 'Antara and Hárith, but after the other seven. Thus we sometimes read of *nine* Mo'allakát. The first author in whom the writer has observed this is the great philosophic historian Ibn Khaldún (A.D. 1332-1406); he mentions instead of Hárith the far more celebrated 'Alkama; whether relying on ancient authority, or by an oversight, we cannot tell. In an excellent collection of forty-nine long poems by Abú Zaid al-Korashí (date unknown) Mofaddal's seven poets appear in the first class, "the necklaces;" but Nábigha and A'shá are each represented by a different piece from that usually reckoned among the Mo'allakát. By this editor the name "golden poems," which, as we have seen, sometimes occurs as a synonym of "Mo'allakát," is applied to seven quite distinct songs.[1] This uncertainty as to the selection and the titles may serve as an additional proof that the "suspension," on the Ka'ba or anywhere else, is a fable.

The lives of these seven (or nine) poets were spread over a period of more than a hundred years. The earliest of them, according to the common and probably correct opinion, was AMRAALKAIS (pronounced also Imroolkais, Imraalkais, &c.), regarded by many as the most illustrious of Arabian poets. His exact date cannot be determined; but probably the best part of his career fell within the first half of the 6th century. He was a scion of the royal house of the tribe Kinda, which lost all its power at the death of King Hárith ibn 'Amr in the year 529.[2] The poet's royal father, Hojr, by some accounts a son of this Hárith, was killed by Bedouins. The son led an adventurous life as a refugee, now with one tribe, now with another, and appears to have died young. The anecdotes related of him—which, however, are very untrustworthy in detail—as well as his poems, imply that the glorious memory of his house and the hatred it inspired were still comparatively fresh, and therefore recent.

The Mo'allaka of 'AMR hurls defiance against the king of Híra, 'Amr son of Mundhir, who reigned from the summer of 554 till 568 or 569, and was afterwards slain by our poet.[3] This prince is also addressed by HÁRITH in his Mo'allaka. Of TARAFA, who is said to have attained no great age, a few satirical verses have been preserved, directed against this same king. This agrees with the fact that a grandson of the Kais ibn Khálid, mentioned as a rich and influential man in Tarafa's Mo'allaka (v. 80 or 81), figured at the time of the battle of Dhú Kár, in which the tribe Bakr routed a Persian army. This battle falls between A.D. 604 and 610 (Nöldeke's *Tabarí*, p. 311).

The Mo'allaka of 'ANTARA and that of ZOHAIR contain allusions to the feuds of the kindred tribes 'Abs and Dhobyán. Famous as these contests were, their time cannot be ascertained. But the date of the two poets can be approximately determined from other data. Ka'b, son of Zohair, composed first a satire, and then, in the year 630, a eulogy on the Prophet; another son, Bojair, had begun, somewhat sooner, to celebrate Mohammed. 'Antara killed the grandfather of the Ahnaf ibn Kais who died at an advanced age in A.D. 686 or 687; he outlived 'Abdalláh ibn Simma, whose brother Doraid was a very old man when he fell in battle against the Prophet (early in A.D. 630); and he had communications with Ward, whose son, the poet 'Orwa, may perhaps have survived the flight of Mohammed to Medina. From all these indications we may place the productive period of both poets in the end of the 6th century.[4] The historical background of 'Antara's Mo'allaka seems to lie somewhat earlier than that of Zohair's.

To the same period appears to belong the poem of 'ALKAMA, which, as we have seen, Ibn Khaldún reckons amongst the Mo'allakát. This too is certainly the date of NÁBIGHA, who was one of the most distinguished of Arabic poets. For in the poem often reckoned as a Mo'allaka, as in many others, he addresses himself to the above-named No'mán, king of Híra, who reigned in the two last decades of the 6th century. The same king is mentioned as a contemporary in one of 'Alkama's poems.

The poem of A'SHÁ, which Mofaddal placed among the Mo'allakát, contains an allusion to the battle of Dhú Kár (under the name "Battle of Hinw," v. 62). This poet, not less famous than Nábigha, lived to compose a poem in honour of Mohammed, and died not long before A.D. 630.

LABÍD is the only one of these poets who embraced Islam. His Mo'allaka, however, like almost all his other poetical works, belongs to the pagan period. He is said to have lived till 661 or even later; certainly it is true of him, what is asserted with less likelihood of several others of these poets, that he lived to a ripe old age.

We have already mentioned that the old Arabic poetry was transmitted not by manuscripts but simply through oral tradition. Many pieces, especially the shorter ones, may have owed their preservation to their hold on the popular memory. But, fortunately, there was a class of men who made it their special business to learn by rote, and repeat, the works either of a single poet or of several. The poets themselves used the services of such rhapsodists (*ráwis*). The last representative of this class is Hammád, the man who formed the collection of Mo'allakát; but he, at the same time, marks the transition from

[1] See Nöldeke, *Beiträge*, p. xxi., and the catalogue of the Arabic codd. in the British Museum, p. 480 *sqq.*

[2] See *Tabarí's Geschichte der Perser und Araber . . . übersetzt von Th. Nöldeke* (Leyden, 1879), p. 171.

[3] See Nöldeke's *Tabarí*, pp. 170, 172.

[4] This evidence might be supplemented from a poem in Zohair's name, whose author describes himself as a man of ninety years, and in which the downfall of King No'mán of Híra (A.D. 601, see *Tabarí*, p. 347) is spoken of as a not very recent event. But the genuineness of this poem is more than doubtful (see Ahlwardt, *op. cit.* p. 64, and C. J. Lyall in the *Academy*, March 13, 1880, p. 192).

the rhapsodist to the critic and scholar. Now, when we consider that more than a century—in some cases two centuries—elapsed before the poems were fixed by literary men, we must be prepared to find that they have not retained their original form unaltered. The most favourable opinion of the rhapsodists would require us to make allowance for occasional mistakes; expressions would be interchanged, the order of verses disarranged, passages omitted, and probably portions of different poems pieced together. The loose structure of the ancient poems rendered them peculiarly liable to corruptions of this kind. But the fact is that Hammád in particular dealt in the most arbitrary fashion with the enormous quantity of poetry which he professed to know thoroughly. He is even charged with falsifications of all sorts in this department. Of others, again—and notably of the great philologist Khalaf, "the Red"—it is credibly reported that they used their intimate knowledge of the style and language of the ancients to pass off whole poems of their own making as the productions of earlier authors. The worst anticipations are only too completely confirmed by an examination of such pieces as are still preserved, as is shown most conclusively in Ahlwardt's *Bemerkungen*, already cited. The seven Mo'allakát are indeed free from the suspicion of forgery, but even in them verses are frequently transposed; in all there are lacunæ; and probably all contain verses which do not belong to them. Some of them have more than one introduction. This is the case even with the poem of 'Amr, although, as the finest panegyric of his very powerful tribe, it must have had a wide circulation. The true introduction begins at v. 9; before that we find another which certainly does not belong to this poem, and can hardly be the work of the same poet. 'Amr lived in the desert regions near the lower Euphrates, under the Persian dominion; whereas the author of v. 8 boasts of his carousals in several parts of Roman Syria, and in v. 1 he speaks of drinking wine from a place in Northern Syria. It is evident that all attempts to restore the original order, to fill up blanks, or to remove interpolations, can only be carried to a certain degree of probability at the best; there must always be a large subjective element in judgments on points of the kind. Still less can we hope to discover and rectify the minor changes, in single expressions or grammatical forms, which the text may have undergone before it was fixed in writing. It may be remarked in this connexion that where any ancient song has been transmitted through two different grammatical schools it generally appears in two considerably divergent forms, each having been taken down from the lips of a separate ráwí. Of secondary importance are the errors due to later copyists. Considerable as these often are, we are, at least in many cases, better able to correct them.

Even the masters of old Arabian poetry do not exhibit such characteristic differences in their general manner and style as to leave in the mind a clear idea of their individuality. A few distinct poetic types emerge, but the great majority of these poets present a somewhat monotonous aspect to the Western scholar, who indeed can at best have but a very imperfect feeling for *nuances* of style in this field. But if we are thus unable to isolate the various constituent parts of this poetical literature, and pass a critical opinion on each, we do get from this literature, as a whole, what is of far greater importance than an æsthetic estimate of this or that particular poet, viz. a poetic picture of the whole life and activity of that remarkable people which, amid the endless agitation and endless sameness of its existence, and in an extremely inhospitable region, was preparing one of the mightiest revolutions in the history of the world. This collective impression is hardly impaired by the involuntary alterations made by the ráwís; nor is it greatly distorted by the forgers of the 2d century of Islam, who were thoroughly familiar with the spirit and style of antiquity, and seldom did violence to them.

The critics of the 2d and 3d centuries A.H. unanimously ranked the poets of the heathen period above those of Islam; and in that verdict we must concur. The older Moslem poets were for the most part mere Epigoni, content, for better or worse, to borrow the style of their pagan predecessors. It is only natural, therefore, that the seven best poems should have been selected from the productions of heathenism. But how these particular seven came to be fixed upon, it is difficult to decide. It is remarkable that people who knew thousands of such poems should have agreed as to the superiority of five, and only differed about two. No doubt the selection was greatly influenced by the widely-established reputation of certain poets, like Amraalkais, Zohair, and Ṭarafa; while in other cases single poems, such as that of 'Amr, stood in high repute for special reasons. Still, even we, with a much narrower range of selection, should hardly pick out these seven as the finest. In all probability our choice would not light on a single one of them. The truth is, our æsthetic ideal is essentially different from that of those old *littérateurs*. And, while we may certainly consider our own taste, formed on the model of the Greeks and the best of the moderns, to be on the whole purer than theirs, we must not forget that they had the advantage of perfect knowledge of the language and the subject-matter, and could thus perceive a multitude of beautiful and delicate touches, which we either miss entirely or realize with laborious effort. The world of the old Arabian poet lay at an infinite remove from ours. His mental horizon was narrow; but within that horizon every minute detail was seized and designated with precision. Among the nomads, for example, the smallest point of the horse or camel that the eye can see has its importance; the language has precise and generally understood words for them all, where ours has only technical terms. It is the same with all the physical properties of the animal—its paces, etc. Thus, when a poet faithfully described the exterior and the deportment of his camel, that was to his hearers—and the same is true of later critics—a genuine pleasure, because the description conveyed to them a definite pictorial impression. But we do not understand the details of the picture; or, when at best with all the resources of tradition and natural history we have gained some tolerable comprehension of them, the whole still leaves us indifferent. A camel to us is simply not a poetical object; and even a horse ceases to be æsthetically interesting—except perhaps to a sportsman—when one is asked to go over his points in detail. For this reason we are apt to find a great part of Ṭarafa's Mo'allaḳa, and many parts of the poems of Amraalḳais, viewed as poetry, distasteful rather than interesting. More attractive are the descriptions of the life and habits of wild animals in the desert, such as the wild ass and some species of antelope, which the poets are fond of introducing (see, *e.g.*, the Mo'allaḳa of Labid). There are also many vivid sketches from nature to be met with,—nature, of course, as seen in the very monotonous Arabian landscape. Monotony, indeed, is a predominant characteristic of this poetry. When one first reads poems where the bard begins by shedding tears over the scarcely perceptible traces of the dwelling of his beloved in years gone by, one's sympathy is aroused. But when poem after poem is found to commence with the same scene, and possibly with almost the same words, the emotion is somewhat damped. No doubt such occurrences must really have been very common in the nomad life; nevertheless the suspicion becomes at last irresistible that for the most part all this is pure fiction. Nor can we be sure that the

poets are always to be taken *au sérieux* when they describe those carousals, and other adventures in peace and war, of which they love to boast. They are probably more serious in the narratives of their love experiences: these are often very highly coloured, and yet are always pervaded by a certain natural refinement, which is too often wanting in the later erotic poetry of the Moslems. But there, too, our enjoyment is frequently marred by minute and even prosy descriptions of the physical charms of the object of affection.

The lyrical and even the more rhetorical passages of the poems make in general a deeper impression upon us than the descriptive portions, to which they owe their distinctive character, and which are often intimately blended with the former. When those old Arabs are really moved by love, or rage, or grief, when personal or tribal vanity vents itself in immoderate boasting, invective, or banter, then they strike chords that thrill our breasts. In those passages where genuine human feeling is stirred, they also display far greater individuality than in the more conventional descriptions. Especially affecting are the numerous passages or complete poems which mourn over the beloved and venerated dead. Their sober practical philosophy too, as it is presented in the Moʻallaḳa of Zohair and in many of Labíd's poems, is really impressive.

The Moʻallaḳát are highly characteristic specimens of this poetry. They exhibit nearly all its merits as well as most of its defects. Amongst its merits we ought, perhaps, to include the unfailing regularity of the verse. That a people living under such extremely simple conditions should have cultivated a purely quantitative metre, so euphonious and so rigorously adhered to, is a fact worthy of our highest admiration. It is one evidence of that sense of measure and fixed form which is, in other directions also, a marked feature in the life and speech of the Arabs. The mere fact that in their verses they give so much attention to elegance of expression deserves commendation. Amongst the defects of this poetry we must emphasize the loose connexion between the separate parts. *We* require a poem, like any other work of art, to be a compact unity; the Arabs and many other Orientals lay all the stress on the details. In the Moʻallaḳa of Ṭarafa, for instance, after the poet has spoken long enough about his beloved, he starts off in this fashion: "But I banish care when it comes near with a"—she-camel of such and such qualities, and then proceeds to give a description of his riding-camel. Equally abrupt transitions occur in almost all these poems, generally more than once in the same poem. In many cases a sort of unity is preserved by making the different sections represent so many scenes from the life of the poet or from the common life of the Bedouins; but even then there is something unsatisfactory in the want of real connexion. It does not mend matters much when the poet keeps up a merely mechanical transition; as, for example, when he speaks first of his camel, then with the words "it is as swift as a wild ass which," &c., passes to a description of that animal, and again proceeds, "or as swift as an ostrich which," &c., in order to introduce the ostrich.

This loose structure of the poems explains the fact that from a very early period particular pieces were culled from larger works and recited by themselves. For the town-Arabs of later times this procedure was especially convenient. For them the wild ass or oryx-antelope had little attraction; and on the camel they bestowed about as much notice as we do on our dray-horses and waggons. But the love and hate, the pride and scorn, the fierce lust of revenge and the wailing grief, the bravery and the gaiety, which breathed through the old Bedouin songs, had an intense fascination for them. We see that their attitude towards that poetry had in some degree approximated to our own. Hence it is that some anthologies from the old poetry, made by men of learning and ability, with an eye to contemporary tastes, are on the whole much more pleasing to us than the complete poems themselves. This is eminently true of the excellent collection edited by Abú Tammám, himself a considerable poet (first half of the 9th century), under the title "Ḥamása" (Valour). This collection, which, however, embraces many pieces of the Moslem period, is certainly fitted to give a European a rather too favourable idea of ancient Arabic poetry. Whoever wishes really to know that poetry—and without this knowledge it is impossible to understand the Arabs themselves or their language—must betake himself to those which, like the Moʻallaḳát and others, have been preserved more or less in their integrity.

The Moʻallaḳát have been repeatedly printed, separately and collectively, both in the West and the East, generally with an Arabic commentary. A good commentary by a competent European is a real desideratum. A work of this kind would do more for the understanding of the poems than any poetical translation, which must always fail in rendering these definite concrete expressions of the Arabs for which we possess neither the idea nor the image. A translation must either be a mere paraphrase or else substitute something utterly vague. (TH. N.)

MOBILE, a city and port of entry of the United States, the capital of Mobile county, and, though not the capital, the largest city of Alabama, lies 140 miles east of New Orleans, on a sandy plain on the west bank of Mobile river, one of the arms of the Alabama. The municipal boundary includes an area about 6 miles long by 2 or 3 in breadth; but, excluding the suburban villas scattered about the nearer hills, the portion occupied by the buildings of the city proper is not more than a mile square. In the matter of paving and shade the streets are generally good, and Government Street especially, with its fine oak trees and gardens, forms an attractive promenade. Besides the spacious granite building erected in 1859 to accommodate the Custom-House, the Post Office, and the United States courts, the principal edifices are the Roman Catholic cathedral of the Immaculate Conception (1833), Christ Church (Episcopal) (1837), the City Hospital (1830), the United States Marine Hospital (1836), the Providence Infirmary, the conjoint market-house and municipal buildings, Barton Academy (occupied by the high schools), and the Alabama Medical College (founded in 1859). About 6 miles out, at Spring Hill, is the Jesuit College of St Joseph, established by Bishop Portier in 1832. As a commercial centre Mobile is in some respects very favourably situated. It is the only port of Alabama; the estuary on which it stands is the outlet for several navigable rivers; and it is the seaward terminus of the Mobile and Ohio railroad, the Mobile and Montgomery, and the Grand Trunk. But, on the other hand, it lies 25 miles from the coast; the lagoon-like bay cut off from the Gulf of Mexico by the narrow isthmus of Mobile Point is extremely shallow; and in 1879 no vessel drawing more than 13 feet could load and unload in the harbour with safety. Since 1827, it is true, various works have been undertaken to improve the approaches: the Choctaw Pass and the Dog River Bar, which had formerly a depth of little more than 5 and 8 feet respectively, were deepened to 17 feet by 1882; but Mobile will not take rank as a satisfactory ocean port till the scheme (now in operation) for constructing a wide channel more than 20 feet deep right through the bay has been fully carried out. The cost of the necessary works being beyond the power both of the city and State, Congress has granted $270,000 for the purpose of widening the channel to 200 feet, and deepening it to 23 feet. A private company, established in 1876, has built a breakwater in the bay, and greatly increased the safety of the harbour. For the years between 1855 and 1859 the average value of exports and imports was respectively

$23,419,266 and $711,420; the following figures for recent years show a considerable decline on the total:—

Years ending in June	Exports.	Imports.
1877	$12,784,171	$648,404
1878	9,493,306	1,148,442
1879	6,219,818	544,628
1880	7,188,740	425,519
1881	6,595,140	671,252
1882	3,258,605	396,573

In cotton, which forms the staple export, the falling off is particularly noticeable, 632,308 bales being the average for 1855 to 1859, and 365,945, 392,319, and 265,040 bales the quantities for 1879, 1880, and 1881. A great deal of what comes to the Mobile market is sent to New Orleans for shipment, partly that it may obtain a higher price as "Orleans" cotton. Lumber shingles, turpentine and rosin, fish and oysters, and coal, are also important items, but do not make in the aggregate so much as half the value of the cotton. Among the local industrial establishments are several spinning-mills, breweries, cooperages, shipbuilding yards, foundries, and sash and door works. The market gardeners of the outskirts produce a large quantity of cabbages, potatoes, watermelons, tomatoes, &c., to supply the cities of the western and northern States (value in 1879, $112,520; 1880, $174,483; 1881, $159,706; 1882, $367,194; 1883, estimated $700,000). Though in 1820 it had no more than 2672 inhabitants, Mobile had 31,255 in 1880; the figures for the intermediate decades being 3194 (1830), 12,672 (1840), 20,515 (1850), 29,258 (1860), and 32,034 (1870).

Founded as a fort by Lemoyne d'Iberville (de Bienville) in 1702, Mobile continued to be the capital of the colony of Louisiana till 1723, when this rank was transferred to New Orleans. The site selected by Lemoyne was probably about 20 miles above the present position, which was first occupied after the floods of 1711. By the Treaty of Paris, 1763, Mobile and part of Louisiana were ceded to Britain; but in 1780 the fort (now Fort Charlotte) was captured by the Spanish general Galvez, and in 1783 it was recognized as Spanish along with other British possessions on the Gulf of Mexico. General Wilkinson, ex-governor of Louisiana, recovered the town for Louisiana in 1813, and in 1819, though its population did not exceed 2500, it was incorporated as a city. In 1864-65 Mobile and the neighbourhood was the scene of important military and naval engagements. The Confederates had surrounded the city by three lines of defensive works, but the defeat of their fleet by Admiral Farragut, and the capture of Fort Morgan, Spanish Fort, and Fort Blakelly, led to its immediate evacuation. As a municipal corporation, Mobile had got into such financial difficulties by 1879 that its city charter was repealed, and a board of commissioners established for the liquidation of its debt of $2,497,856.

MÖBIUS, August Ferdinand (1790-1868), astronomer and mathematician, was born at Schulpforta, November 17, 1790. At Leipsic, Göttingen, and Halle he studied for four years, ultimately devoting himself to mathematics and astronomy. In 1815 he settled at Leipsic as privat-docent, and the next year became extraordinary professor of astronomy in connexion with the university. Later he was chosen director of the university observatory, which was erected (1818-21) under his superintendence. In 1844 he was elected ordinary professor of higher mechanics and astronomy, a position which he held till his death, September 26, 1868. His doctor's dissertation, *De computandis occultationibus fixarum per planetas* (Leipsic, 1815), established his reputation as a theoretical astronomer. *Die Hauptsätze der Astronomie* (1836), *Die Elemente der Mechanik des Himmels* (1843), may be noted amongst his other purely astronomical publications. Of more general interest, however, are his labours in pure mathematics, which appear for the most part in Crelle's Journal from 1828 to 1858. These papers are chiefly geometrical, many of them being developments and applications of the methods laid down in his great work, *Der Barycentrische Calcul* (Leipsic, 1827), which, as the name implies, is based upon the properties of the mean point or centre of mass. Any point in a plane (or in space) can be represented as the mean point of three (or four) fixed points by giving to these proper weights or coefficients,—an obvious principle which leads in the hands of Möbius to what no doubt is the chief novel feature of the work, a system of homogeneous coordinates. Besides this, however, the work abounds in suggestions and foreshadowings of some of the most striking discoveries in more recent times—such, for example, as are contained in Grassmann's *Ausdehnungslehre* and Hamilton's *Quaternions*. He must be regarded as one of the leaders in the introduction of the powerful methods of modern geometry that have been developed so extensively of late by Von Standt, Cremona, and others.

MOCHÁ, a town of Yemen on the coast of the Red Sea, in E. long. 43° 20′, N. lat. 13° 19′. The point of the coast where Mochá lies appears to have owed early importance to its good anchorage, for the Muza of the *Periplus* (*Geog. Gr. Min.*, i. 273 *sqq.*), a great seat of the Red Sea trade in antiquity, seems to be identical with the modern Múza' (Yáḳút, iv. 680; Niebuhr, *Desc. de l'Arabie*, p. 195), a few miles inland from Mochá. Mochá itself is a modern town, which rose with the coffee trade into short-lived prosperity. The French expedition of 1709 found it a place of some 10,000 inhabitants, and its importance had increased half a century later, when Niebuhr visited it. The chief trade was then with British India. Lord Valencia in 1806 still found the town to present an imposing aspect, with its two castles, minarets, and lofty buildings; but the population had sunk to 5000. The internal disorders of Arabia and the efforts of Mohammed Ali to make the coffee trade again pass through India accelerated its fall, and the place is now a mere village. Mochá never produced coffee, and lies indeed in a quite sterile plain; the European name of Mochá coffee is derived from the shipment of coffee there. The patron saint, Sheikh Shadali, was, according to legend, the founder of the city and father of the coffee trade.

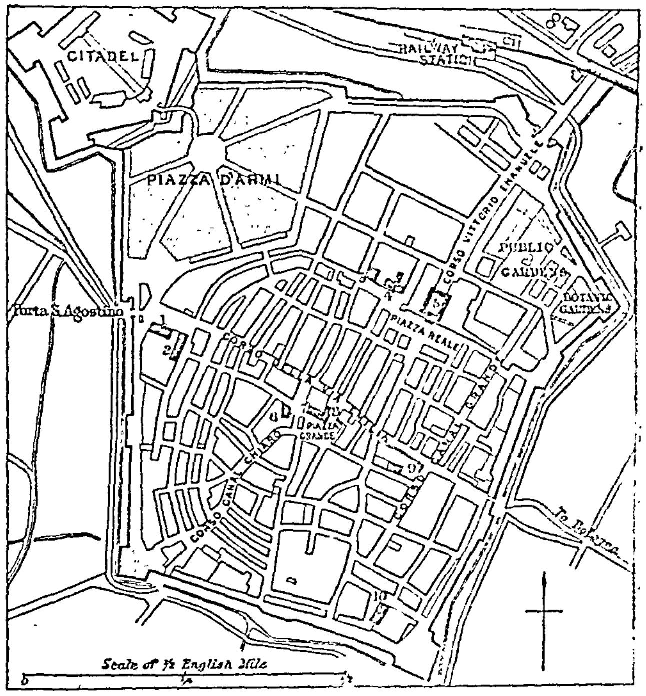
MOCKING-BIRD, or Mock-Bird (as Charleton, Ray, and Catesby wrote its name), the *Mimus polyglottus* of modern ornithologists, and the well-known representative of an American group of birds usually placed among the Thrushes (*q.v.*), *Turdidæ*, though often regarded as forming a distinct section of that Family, differing by having the tarsus scutellate in front, while the typical Thrushes have it covered by a single horny plate. The Mocking-bird inhabits the greater part of the United States, being in the north only a summer-visitant; but, though breeding yearly in New England, is not common there, and migrates to the south in winter, passing that season in the Gulf States and Mexico. It appears to be less numerous on the western side of the Alleghanies, though found in suitable localities across the continent to the Pacific coast, but not farther northward than Wisconsin, and it is said to be common in Kansas. Audubon states that the Mocking-birds which are resident all the year round in Louisiana attack their travelled brethren on the return of the latter from the north in autumn. The names of the species, both English and scientific, have been bestowed from its capacity of successfully imitating the cry of many other birds, to say nothing of other sounds, in addition to uttering notes of its own which possess a varied range and liquid fulness of tone that are unequalled, according to its admirers, even by those of the Nightingale (*q.v.*). This opinion may perhaps be correct; but, from the nature of the case, a satisfactory judgment can scarcely be pronounced, since a comparison of the voice of the two songsters can only be made from memory, and that is of course affected by associations of ideas which would preclude a fair estimate. To hear either bird at its best it must be at liberty; and the bringing together of captive examples, unless it could be done with so many of each species as to ensure an honest trial, would be of little avail. Plain in plumage, being greyish-brown above and dull white below, while its quills are dingy black, variegated with white, there is little about the Mocking-bird's appear-

ance beyond its graceful form to recommend it; but the lively gesticulations it exhibits are very attractive, and therein its European rival in melody is far surpassed, for the cock-bird mounts aloft in rapid circling flight, and, alighting on a conspicuous perch, pours forth his ever-changing song to the delight of all listeners; while his actions in attendance on his mate are playfully demonstrative and equally interest the observer. The Mocking-bird is moreover of familiar habits, haunting the neighbourhood of houses, and is therefore a general favourite. The nest is placed with little regard to concealment, and is not distinguished by much care in its construction. The eggs, from three to six in number, are of a pale bluish-green, blotched and spotted with light yellowish-brown. They, as well as the young, are much sought after by snakes, but the parents are often successful in repelling these deadly enemies, and are always ready to wage war against any intruder on their precincts, be it man, cat, or hawk. Their food is various, consisting of berries, seeds, and insects.

Some twelve or fourteen other species of *Mimus* have been recognized, mostly from South America; but *M. orpheus* seems to be common to some of the Greater Antilles, and *M. hilli* is peculiar to Jamaica, while the Bahamas have a local race in *M. bahamensis*. The so-called Mountain Mocking-bird (*Oreoscoptes montanus*) is a form not very distant from *Mimus*; but, according to Mr. Ridgway, it inhabits exclusively the plains overgrown with *Artemisia* of the interior tableland of North America, and is not at all imitative in its notes, so that it is an instance of a misnomer. Of the various other genera allied to *Mimus*, those known in the United States as Threshers, and belonging to the genus *Harporhynchus*—of which six or eight species are found in North America, and are very Thrush-like in their habits—must be mentioned; but there is only room here to dwell on the Cat-bird (*Galeoscoptes carolinensis*), which is nearly as accomplished an imitator of sounds as its more celebrated relative, with at the same time peculiar notes of its own, from one of which it has gained its popular name. The sooty-grey colour that, deepening into blackish-brown on the crown and quills, pervades the whole of its plumage—the lower tail-coverts, which are of a deep chestnut, excepted—renders it a conspicuous object; and though, for some reason or other, far from being a favourite, it is always willing when undisturbed to become intimate with men's abodes. It has a much wider range on the American continent than the Mocking-bird, and is one of the few species that are resident in Bermuda, while on more than one occasion it is said to have appeared in Europe.

The name Mocking-bird, or more frequently Mock-Nightingale, is in England occasionally given to some of the Warblers (*q.v.*), especially the Blackcap (*Sylvia atricapilla*), and the Sedge-bird (*Acrocephalus schœnobænus*). In India and Australia the same name is sometimes applied to other species. (A. N.)

MODENA, one of the principal cities of Northern Italy, formerly the capital of a duchy, and still the chief town of a province and the seat of an archbishop, is situated in the open country in the south side of the valley of the Po, between the Secchia to the west and the Panaro to the east. By rail it is 31 miles E.S.E. of Parma, 24 W.N.W. of Bologna, and 37 S. of Mantua. The observatory stands 135 feet above the level of the sea, in 44° 38′ 52″ N. lat. and 10° 55′ 42″ E. long. Dismantled since 1816, and now largely converted into promenades, the fortifications still give the city an irregular pentagonal contour, modified at the north-west corner by the addition of a citadel also pentagonal. Within this circuit there are various open areas—the spacious Piazza d'Armi in front of the citadel, the public gardens in the north-east of the city, the Piazza Grande in front of the cathedral, and the Piazza Reale to the south of the palace. The Æmilian Way crosses obliquely right through the heart of the city, from the Bologna Gate in the east to that of Sant' Agostino in the west. Commenced by the countess Matilda in 1099, after the designs of Lanfranc, and consecrated in 1184, the cathedral (St Geminian's) is a low but handsome building, with a lofty crypt, three eastern apses, and a façade still preserving some curious sculptures of the 12th and 15th centuries. The bell-tower, named La Ghirlandina from the bronze garland surrounding the weathercock, is lined with white marble, and is 315 feet high; in the basement may be seen the wooden bucket captured by the Modenese from the Bolognese in the affray at Zappolino (1325), and rendered famous by Tassoni's *Secchia Rapita*. Of the other churches in Modena, San Pietro has terra-cottas by the local artist Begarelli, and S. Agostino (now S. Michele) contains the tomb of Sigonius and the tombstone of Muratori. The old ducal palace, begun by Duke Francis I. in 1635 from the designs of Avanzini, and finished by Francis Ferdinand V., is an extensive marble building, and now contains the library (*Bib. Palatina*, see vol. xiv. p. 530), picture-gallery, and museum. Many of the best pictures in the ducal collection were sold in the 18th century, and found their way to Dresden. The valuable *Museo Lapidario* in a building near Porta Sant' Agostino is well known to the



Plan of Modena.

1. Museo Lapidario.	4. S. Domenico.	7. Cathedral.
2. S. Agostino.	5. Royal Palace.	8. Campanile Ghirlandina.
3. Academy of Fine Arts.	6. Archbishop's Palace.	9. University.
	10. S. Pietro.	

classical antiquary through Cavedoni's *Dichiarazione degli antichi marmi Modenesi* (1828), and the supplements in the *Memoirs* of the Academy, vol. ix., &c. The university of Modena, originally founded in 1683 by Francis II., is mainly a medical and legal school, but has also a faculty of physical and mathematical science. It has about twenty-five professors, and from 200 to 250 students; a library of 20,000 volumes, an observatory, botanical gardens, an ethnographical museum, &c. The old academy of the *Dissonanti*, dating from 1684, was restored by Francis in 1814, and now forms the flourishing Royal Academy of Science and Art (*Memoirs* since 1833); and there are besides in the city an Italian Society of Science founded by Anton Mario Lorgna, an academy of fine arts, a military college (1859), an important agricultural college, and a lyceum and gymnasium, both named after Muratori. In industrial enterprise the Modenese show but little activity, silk and linen goods and iron-wares being almost the only products of any note. Commerce is stimulated by a good position in the railway system, and by a canal which opens a water-way by the Panaro and the Po to the Adriatic. The population of the city was 32,248 in 1861, and 30,854 in 1871; that of the commune 55,512 in 1861, and 58,058 in 1881.

The Duchy of Modena, an independent sovereign state

(1452 to 1859), ultimately extended from the Po to the Mediterranean, and was bounded N. by Lombardy and the Papal States, E. by the Papal States and Tuscany, S. by Tuscany, Sardinia, and the Mediterranean, and W. by Sardinia and the duchy of Parma. Its greatest length, from Porto-Vecchio, on its northern frontier towards Mantua, to the outlet of the Parmignola torrent, on the Sardinian frontier, was 84½ miles; and its greatest width, from the pass of Calama, on the Papal and Tuscan frontier, to the right bank of the Enza, on the frontier of Parma, was 37 miles. The area was 2371 square miles, of which three-fifths were mountainous. In 1855 the population was 606,159. The duchy had six provinces—Modena, Reggio, Guastalla, Frignano, Garfagnana, Massa-Carrara.

Modena is the ancient Mutina, which was annexed by the Romans along with the rest of the territory of the Boii. In 183 B.C. Mutina became the seat of a Roman colony. During the civil wars Marcus Brutus held out within its walls against Pompeius in 78 B.C., and in 44 B.C. the place was defended by D. Brutus against M. Antony. The 4th century found Mutina in a state of decay; the ravages of Attila and the troubles of the Lombard period left it a ruined city in a wasted land. In the 8th century its exiles founded, at a distance of 4 miles to the north-west, a new city, Città Geminiana (still represented by the village of Cittanova); but about the close of the 9th century Modena was restored and refortified by its bishop, Laedoinus. When it began to build its cathedral (1099 A.D.) the city was part of the possessions of the countess Matilda of Tuscany; but when, in 1184, the edifice was consecrated by Lucius III., it was a free community. In the wars between Frederick II. and Gregory IX. it sided with the emperor, though ultimately the papal party was strong enough to introduce confusion into its policy. In 1288 Obizzo d'Este was recognized as lord of the city; after the death of his successor, Azzo VIII. (1308), it resumed its communal independence; but by 1336 the Este family was again in power. Constituted a duchy in 1452 in favour of Borso d'Este, and enlarged and strengthened by Hercules II., it became the ducal residence on the incorporation of Ferrara with the States of the Church (1598). Francis I. (1629-1658) erected the citadel and commenced the palace, which was largely embellished by Francis II. Rinaldo (*ob.* 1737) was twice driven from his city by French invasion. To Francis III. (1698-1780) the city was indebted for many of its public buildings. Hercules III. (1727-1803) saw his states transformed by the French into the Cispadine Republic, and, having refused the principality of Breisgau and Ortenau, offered him in compensation by the treaty of Campo Formio, died an exile at Treviso. His only daughter, Maria Beatrice, married Ferdinand of Austria (son of Maria Theresa), and in 1814 their eldest son, Ferdinand, received back the *Stati Estensi.* His rule was subservient to Austria, reactionary, and despotic. On the outbreak of the French Revolution of 1830, Francis IV. seemed for a time disposed to encourage the corresponding movement in Modena; but no sooner had the Austrian army put an end to the insurrection in Central Italy than he returned to his previous policy. Francis Ferdinand V., who succeeded in 1846, followed in the main his father's example. Obliged to leave the city in 1848, he was restored by the Austrians in 1849; ten years later, on 20th August 1859, the representatives of the Modenese, under the direction of Carlo Farini, declared their territory part of the kingdom of Italy, and their decision was confirmed by the plebiscite of 1860.

Natives of Modena are Fallopius the anatomist, Tarquinia Molza, Sadoletius, Sigonius, Tassoni, and Cavedoni the archæologist; the names of Zaccaria, Tiraboschi, and Muratori are associated with its library. Tiraboschi's *Bibliotheca Modenensis*, 6 vols., contains an account of all the literary personages of the duchy.

See Vedriani, *Storia di Modena*, 1666; Tiraboschi, *Mem storiche modenesi*, 1793; Scharfenberg, *Gesch. des Herzogth. Modena*, 1859; Oreste Raggi, *Modena descritta*, 1860; Baraldi, *Storia di Modena*; Valdrighi, *Diz. Storico, &c., delle contrade di Modena*, 1879-80; Crespellani, *Guida di Modena*, 1879; Galvani, *Mem. stor. intorno la vita di Francesco IV.*, 4 vols.

MODICA, a city of Italy, in the province of Syracuse in Sicily, 8 miles from the south coast, on the line of railway decreed in 1879 between Syracuse and Licata. It has increased its communal population from 30,547 in 1861 to 41,231 in 1881, and is a well-built and flourishing place. Of note among the public buildings are the old castle on the rock, the mediæval convent of the Franciscans, and the churches of S. Maria del Carmine (1150) and S. Maria di Betlem—this last containing ruins of the ancient temple destroyed by the earthquake of 1693. Modica is the point from which the remarkable prehistoric tomb and dwelling-caves of Val d'Ispica are usually visited. An early dependency of Syracuse, Motyca or Mutyca was in Cicero's days a fairly important municipium. In modern times it was held as a countship by the dukes of Alba. Placido Caraffa has written a prolix history of the city, which may be found in Grævius, *Thes. Ant. et Hist. Ital.*, vol. xii.

MOE, JÖRGEN ENGEBRETSEN (1813-1882), Norwegian poet and comparative mythologist, was born at Hole in Sigdal, Ringerike, Norway, on 22d April 1813, and entered the university of Christiania as a theological student at the age of seventeen. After leaving the university in 1839 he acted as tutor in various schools and families, and in 1845 was appointed professor of theology in the Military School of Norway, which post he held until 1853, when he became resident chaplain in his native parish of Sigdal. In 1863 he received the living of Bragernæs, Drammen; in 1870 that of Vest Aker, near Christiania; and in 1875 the bishopric of Christiansand, where he died on 27th March 1882.

Moe's first publication was a volume of Norse "songs, ballads, and staves," which appeared in 1840; it was followed in 1841 by the *Norske Folke-eventyr* (Norwegian Popular Tales), which he had collected along with his schoolfellow Asbjörnsen. The work excited such interest as a contribution to the study of comparative mythology that in 1847 he was sent by the Government through Thelemark and Sætersdal to increase his collection of stories. The second (enlarged) edition, with a preface by Moe, appeared in 1852. In 1851 his *I Brönden og i Tjernet* (In the Well and in the Tarn), a delightful collection of prose stories for children, appeared, and it was followed in 1859 by a volume of poems entitled *En liden Julegave* (A Little Christmas Present). In 1877 he prepared a collected edition of his works in two volumes, the stories he had published along with Asbjörnsen being excluded. Many of the *Folke-eventyr* (*Popular Tales from the Norse*) were translated by Sir George Dasent in 1859.

MŒSIA (in Greek Mysia, or, to distinguish it from the country of the same name in Asia, Mysia in Europe), in ancient geography the territory immediately to the south of the Danube corresponding in the main to Servia and Bulgaria. It became a Roman province between 27 B.C. and 6 A.D., probably about 16 B.C.[1] In the time of Tiberius and Caius the province was under the same governor with Macedonia and Achaia. It was divided by Domitian into two provinces, Mœsia Superior (Servia) and Mœsia Inferior (Bulgaria); and the same emperor completed the great military road along the line of the Danube, increased the strength of the Roman forces in the country, and, by the conquest of Dacia, saved it from the inroads by which it had been harassed from the time of Tiberius. The Goths invaded Mœsia in 250 A.D., and at last, in 395, a number of them, afterwards known as Mœsogoths, obtained permission to settle in the province. The Slavonians and Bulgarians appear in the 7th century.

The boundary between Upper and Lower Mœsia was not marked, as Ptolemy (iii. 9, 10) states, by the river Cebrus or Ciabrus (Cibritza or Zibru), but, as may be inferred from an inscription (6125, *C. Inscr. Lat.*, vol. iii. 2, *additamenta*), lay between Almus (Lom) and Ratiaria (Artcher). Upper Mœsia, or, as it was often called, Mœsia Prima, contained—Singidunum (Belgrade), headquarters of Legio IV. Flavia, and in the 3d century a colonia; Viminacium (Kostolatz), headquarters of Leg. VII. Claud., and designated sometimes municipium Ælium, but more usually colonia (a rank bestowed on it by Gordianus); Bononia (Widin); Ratiaria, which, on the loss of Dacia, became the headquarters of Leg. XIII. gemina, and remained a large town till it was destroyed by Attila; Remesiana (Mustapha Pasha Palanka), which has furnished inscriptions belonging to the unidentified Ulpiana; and Naissus (Nissa or Nish), the birthplace of Constantine the Great. Lower Mœsia (Mœsia Secunda) contained—Oescus (Colonia Ulpia, mod. Gigen), headquarters, after loss of Dacia, of Leg. V. Maced.; Novæ (Sistova), at a late date a camp of Leg. I. Ital., and afterwards chief seat of Theodoric king of the Goths; Nicopolis ad Istrum (Nikup), really on the Iatrus or Yantra, a memorial of Trajan's victory over the Dacians; Pristra (Rustchuk), Asamus (Nicopoli on the Osma), Darostorum (Silistria), Odessus (Varna), Tomi (Kustendje), Troesmis (Iglitza).

See Roesler, *Romanische Studien*, 1871; Pfitzner, *Gesch. der Röm. Kaiser-legionen*, 1881, pp. 152-161; Hahn, in *Dkschr. K. Ak. der Wiss.*, *Ph. H. Cl.*, Vienna, 1861, p. 228.

MOFFAT, a health resort of some note in Scotland, is situated in Upper Annandale, Dumfriesshire, occupying an

[1] See A. W. Zumpt, *Commentat. Epigraph.*, ii. 253 *sqq.*

agreeable position at the base of the Gallow Hill, 63 miles from Edinburgh, and 42 miles from Carlisle by railway. The Spa, which is 1½ miles above the town (525 feet above sea-level), is sulphureous with some saline ingredients, and is used in gout, rheumatism, and dyspepsia. Population (1881) 2161; in the season about 4000.

MOFFAT, ROBERT, D.D. (1795-1883), African missionary, was born at Ormiston, Haddingtonshire, Scotland, on 21st December 1795, of humble parentage. Moffat learned the craft of gardening, but in 1814 offered himself to the London Missionary Society, who, in 1816, sent him out to South Africa. After spending a year in Namaqua Land, with the powerful and dreaded chief Africaner, whom he converted, Moffat returned to Cape Town in 1819, and married Miss Mary Smith, a remarkable woman and most helpful wife. In 1820 Moffat and his wife left the Cape and proceeded to Griqua Town, and ultimately settled at Kuruman, among the Bechuana tribes lying to the west of the Vaal river. Here he worked as a missionary till 1870, when he reluctantly returned finally to his native land. He made frequent journeys into the neighbouring regions, as far north as the Matabele country, to the south of the Zambesi. The results of these journeys he communicated to the Royal Geographical Society (*Jour. R. G. S.*, xxv. xxviii., and *Proc.* ii.), and when in England in 1842 he published his well-known *Missionary Labours and Scenes in South Africa*. Single-handed he translated the whole of the Bible into Bechuana. While solicitous to turn the people to Christian belief and practice, Moffat was perhaps the first to take a broad view of the missionary function, and to realize the importance of inducing the savage to adopt the arts of civilization. He himself was builder, carpenter, smith, gardener, farmer, all in one, and by precept and example he succeeded in turning a horde of bloodthirsty savages into a "people appreciating and cultivating the arts and habits of civilized life, with a written language of their own." Now we find more or less Christianized communities extending from Kuruman to near the Zambesi. Moffat met with incredible discouragement and dangers at first, which he overcame by his strong faith, determination, and genial humour. It was largely due to him that the work of Livingstone, his son-in-law, took the direction which it did. On his return to England, Moffat received a testimonial of about £6000. He died at Leigh, near Tunbridge Wells, 9th Aug. 1883.

See *Scenes and Services in South Africa, the Story of Moffat's Missionary Labours*, London, 1876; and publications of the London Missionary and the B. and F. Bible Societies.

MOGADOR, or SUERAH (Berber *Tasurt*), the most southern seaport town on the Atlantic coast of Morocco, and the capital of the province of Haha, stands from 10 to 20 feet above high water on a projecting ridge of calcareous sandstone in 31° 30′ N. lat. and 10° 44′ W. long. In certain states of wind and sea it is turned almost into an island, and a sea-wall protects the road to Saffi. The streets are regular and, for a Moorish town, broad and clean. Within the walls there are three distinct divisions: the citadels old and new with the government buildings; to the north-west the outer town with its spacious markets in the centre; and at the north-west corner the Mellah, or Jews' quarter. In the citadels the houses are fairly good, and considerable attention is paid to sanitary matters. Water is brought from the Kseb, about 1½ miles to the south, by an aqueduct. The prosperity of Mogador is due to its commerce; only a few gardens break the barrenness of the immediate vicinity. The harbour or roadstead, though apparently protected by the island and quarantine station of Mogador, is extremely dangerous during west and south-west winds. Trade is carried on mainly with Marseilles, London, Gibraltar, and the Canaries,—the principal exports being almonds, goat-skins, gums, olive oil, and ostrich feathers, and the principal imports cotton goods (half of the total) and tea. The average value of the exports for the five years 1877-1881 was about £210,000, the imports rather less. Attention has been frequently directed to the value of Mogador as a health resort, especially for consumptive patients. The climate is remarkably steady: mean temperature of the hottest month 71·06, of coldest month 58·69. The annual rainfall is only 10 or 12 inches, and the rainy days of winter and spring about 28. The sirocco is but rarely felt. The population is about 15,000 (7000 Jews, about 150 foreigners). Jews, Protestants, and Roman Catholics have religious edifices in the town.

A place called Mogador is marked in the 1351 Portulan of the Laurentian Library, and the map in Hondius's *Atlas Minor* shows the island of Mogador *I. Domegador*; but the origin of the present town is much more recent. Mogador was founded by Sultan Mohammed, and completed in 1770. The town received from the Moors the name of Suerah (little picture), while the Portuguese called it after the shrine of Sidi Mogadul, which lies towards the south half-way to the village of Diabat, and forms a striking landmark for seamen. In 1844 the citadel was bombarded by the French.

MOGHILEFF, a north-western government or province of the Russian empire, situated on the upper Dnieper, between the provinces of Vitebsk and Smolensk on the north and east, Tchernigoff and Minsk on the south and west. In the north it is occupied by the watershed which separates the basins of the Dwina and the Dnieper, an undulating tract from 650 to 900 feet above the sea-level, and covered nearly everywhere with forests. This watershed slopes gently to the south, that is, to the valley of the Dnieper, which enters the province from the north-east and flows west and afterwards due south. The southern part of the province is flat and has much in common with the Polyesie of the province of Minsk; it is, however, more habitable, the marshes being less extensive.

The province is covered by the Tertiary formation; Devonian sandstone appears in the north, and Carboniferous limestones in the east. The soil is mostly sand, clay (brick-clay and potter's-clay are not uncommon), and peat-bogs, with a few patches of "black-earth." The climate is rude and wet, the average yearly temperature at the Gorki meteorological observatory being 40°·4 Fahr. (14°·2 in January, and 63°·8 in July); cold nights in summer are often the cause of bad crops. The province has about 1,140,000 inhabitants (947,625 in 1870), mostly White-Russians (78 per cent.), belonging to the Greek Church; Jews are numerous (16 per cent.); Poles, belonging mostly to the nobility, make only 3 per cent. of the population. Agriculture is the chief occupation; nearly one half (46 per cent.) of the surface of the province is under crop; but, except after unusually good harvests, corn is imported, chiefly by the navigable channels of the Dnieper and Sozh. There are many distilleries on the estates of landowners, and wine-spirit is exported. The hemp culture is important; hemp and hemp-seed oil are exported to Riga. The province has one large paper-mill, a few iron and copper works, and minor manufactures.

The province of Moghileff is divided into eleven districts, with the chief towns: Moghileff (40,500 inhabitants), Chausy (4200), Tcherikoff (3900), Gomel (13,030), Gorki, formerly the seat of an agricultural institute (5050), Klimovichi (4000), Mstislavl (6700), Orsha (5350), Rogacheff (7750), Staryi Bykhoff (5200), and Syenno (2550). Of about 80 other municipal towns, we name Shkloff (13,000 inhabitants), Dubrovka (7000), Kricheff (1000).

This province was inhabited in the 10th century by the Krivichi and Radimichi. In the 14th century it became part of Lithuania and afterwards of Poland. Russia annexed it in 1772.

MOGHILEFF ON THE DNIEPER, a town of Russia, capital of the province of same name. It is situated on both banks of the Dnieper, 40 miles south of the Orsha station of the railway between Moscow and Warsaw. A railway along the Dnieper will soon bring Moghileff into railway communication with these capitals.

Moghileff is mentioned for the first time in the 11th century as a dependency of the Vitebsk, or of the Mstislavl principality. At the beginning of the 15th century it became the personal property of the Polish kings. But it was continually plundered—either by Russians, who attacked it six times during the 16th century, or by Cossacks, who plundered it three times. In the 17th century its inhabitants who belonged to the Greek Church suffered much from the persecutions of the Union. In 1651

it surrendered to Russia, but in 1661 the Russian garrison was massacred by the inhabitants. In the 18th century it was taken several times by Russians and by Swedes, and in 1708 Peter I. ordered it to be destroyed by fire. It was annexed to Russia in 1772. Of 40,500 inhabitants two-thirds are Jews and the remainder White-Russians, with a few Poles (2500). Its manufactures are without importance; but one branch of trade, namely, the preparation of skins, has maintained itself for many centuries. The commerce is mostly in the hands of Jews: corn, salt, sugar, and fish are brought from the south, whilst skins and manufactured ware imported from Germany (partly by smugglers) are sent to the southern provinces.

MOGHILEFF ON THE DNIESTER (*Mohîlov*), a district town of Russia, situated in the province of Podolia, on the left bank of the Dniester, 87 miles east-south-east of Kamenets-Podolsk, and 43 miles from the Zhmerinka railway junction. It has 18,200 inhabitants, nearly one-half of whom are Jews; the remainder are Little Russians, Poles (1500), and a few Armenians. The Little-Russian inhabitants of Moghileff carry on agriculture, gardening, wine, and mulberry culture. The Jews and Armenians are engaged in a brisk trade with Odessa, to which they send corn, wine, spirits, and timber, floated down from Galicia, as well as with the interior, to which they send manufactured wares imported from Austria.

Moghileff, named in honour of the Moldavian hospodar Mohila, was founded by Count Potocki about the end of the 16th century. Owing to its situation on the highway from Moldavia to the Ukraine, at the passage across the Dnieper, it developed rapidly. For more than 150 years it was disputed by the Cossacks, the Poles, and the Turks. It remained in the hands of the Poles, and was annexed to Russia in 1795. The Crown purchased it from Count Potocki in 1806.

MOGILAS, PETRUS (*c.* 1600-1647), metropolitan of Kieff from 1632, belonged to a noble Wallachian family, and was born about the year 1600. He studied for some time at the university of Paris, and first became a monk in 1625. He was the author of a *Catechism* (Kieff, 1645) and other minor works, but is principally celebrated for the *Orthodox Confession*, drawn up at his instance by the abbot Kosslowski of Kieff, approved at a provincial synod in 1640, and accepted by the patriarchs of Constantinople, Jerusalem, Alexandria, and Antioch in 1642-3, and by the synod of Jerusalem in 1672. See GREEK CHURCH, vol. xi. p. 158.

There are numerous editions of the *Confession* in Russian; it has been edited in Greek and Latin by Panagiotes (Amsterdam, 1662), by Hofmann (Leipsic, 1695), and by Kimmel (Jena, 1843), and there is a German translation by Frisch (Frankfort, 1727).

MOGUL, or MUGHAL, مغل, the Arabic and Persian form of the word Mongol, usually applied to the Mongol empire in India. See INDIA, vol. xii. p. 793 *sqq.*

MOHÁCS, a market town in the Trans-Danubian county of Baranya, Hungary, stands on the right bank of the west arm of the Danube, 25 miles east-south-east of Pécs (Fünfkirchen), with which it is connected by railway, 45° 58′ N. lat., 18° 37′ E. long. At Mohács there are several churches and schools belonging both to the Roman Catholics and the Calvinists, also the summer palace of the bishop of Pécs, a monastery, an old castle, and a station for steamers plying on the Danube, by which means a considerable commerce in wine and the agricultural produce of the neighbourhood is carried on with Budapest and Vienna. Not far from Mohács are coal mines, and the town is an important coal depôt of the Danubian Steam Navigation Company. The population in 1880 was 12,047 (Magyars, Serbs, and Germans).

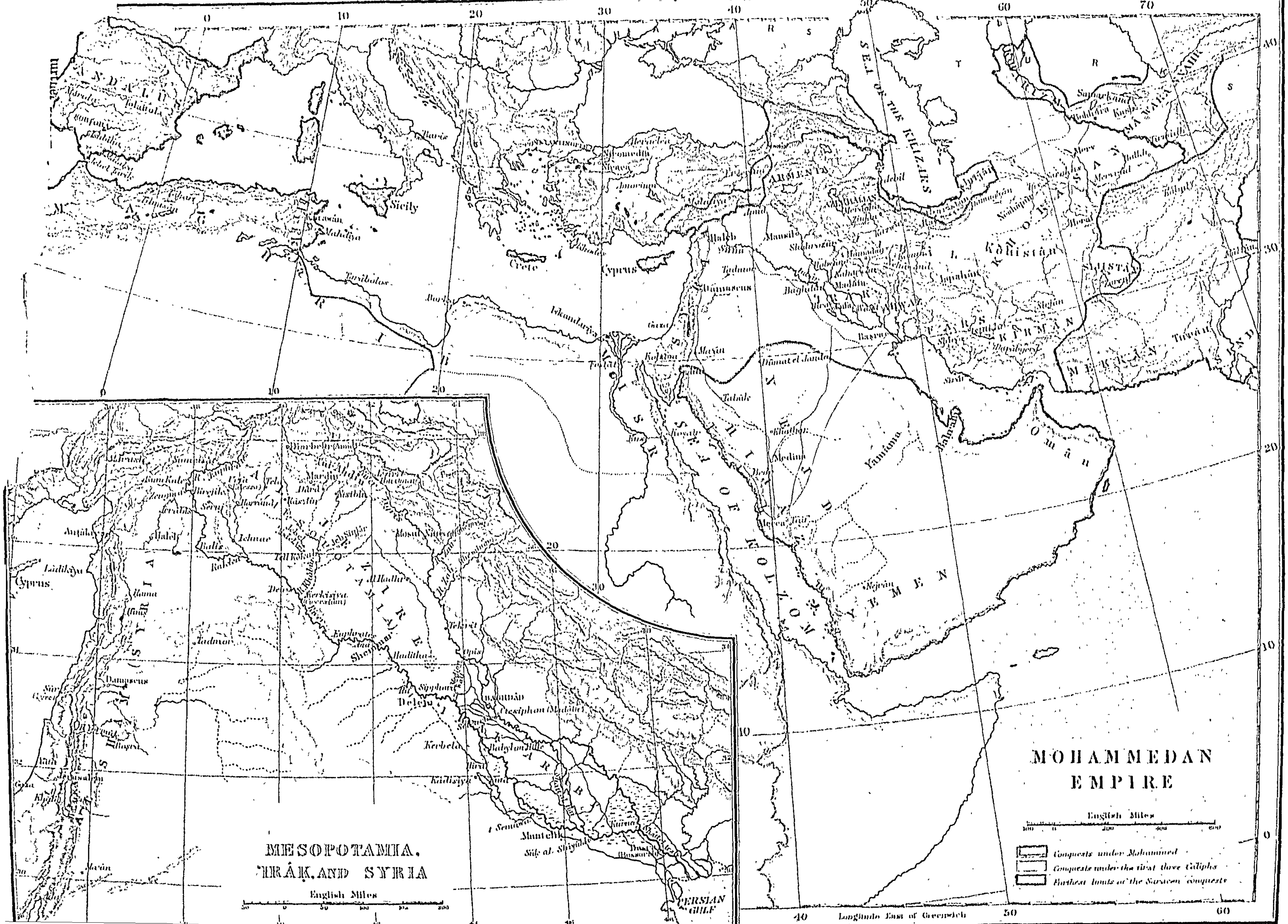
Two great battles fought in the vicinity of the town mark the commencement and close of the Turkish dominion in Hungary. In the first, 29th August 1526, the Hungarian army under Louis II. was annihilated by the Ottoman forces led by Soliman the Magnificent (see vol. xii. p. 369). In the second, 12th August 1687, the Austrians under Charles of Lorraine gained a great and decisive victory over the Turks, whose power was afterwards still further broken by Prince Eugene of Savoy.

MOHAIR is the woolly hair of a variety of the common or domestic goat inhabiting the regions of Asiatic Turkey, of which Angora is the centre, whence the animal is known as the Angora Goat (see GOAT, vol. x. p. 708). Goat's hair has been known and used as a textile material in the East from the most remote periods; but neither the Angora goat nor its wool was known in Western Europe till, in 1655, the animal was described by the naturalist Tournefort. That textures of mohair were in use in England early in the 18th century is obvious from Pope's allusion:—

> "And, when she sees her friend in deep despair,
> Observes how much a chintz exceeds mohair."

Owing, however, to the jealous restrictions of the Turkish power, it was not till 1820 that mohair became a regular article of import into the United Kingdom. In that year a few bales came into the market; but so little was the material appreciated that it only realized 10d. per ℔. In 1870 average mohair fleece was selling at five times that price. From the small beginning of 1820 the imports gradually waxed, and the trade received a very considerable impetus through the introduction in 1836, by Titus Salt, of the analogous fibre alpaca. The increasing demand for and value of mohair early stimulated endeavours to acclimatize the Angora goat in other regions; but all European attempts have failed, owing to humid and ungenial climates. In 1849 a flock was taken by Dr J. P. Davis to the United States of America, and since that time many fresh drafts have been obtained and distributed to Virginia and various Southern States, and to California and Oregon in the west. In these high and dry regions the goats thrive; and the flocks in the Western States now number many thousands. The Angora goat has also been introduced into the Cape of Good Hope with much success. The first importation of mohair from the Cape, made in 1862, amounted to 1036 ℔; and now about one-tenth of the total British supply is received from that source. Mohair has also been received in England from goats reared successfully in Fiji, where they were first introduced in 1874, and there are also thriving flocks in Australia.

The trade in mohair between Asia Minor and western Europe is controlled in Constantinople. There upwards of twenty varieties of fleeces are distinguished according to the localities of their production, the richest and most lustrous qualities being produced in hilly and forest regions, while the fleeces from the open plains are comparatively kempy, coarse, and cottony. From the Lake Van district on the eastern borders of Asiatic Turkey a distinct and inferior variety of wool is obtained. It is known in commerce as Van mohair, and consists, to the extent of about 70 per cent., of white wool slightly streaked with black, with 30 per cent. of coloured red and black wool. At Konieh in the south, also, an inferior mohair known as Pelotons is produced, 80 per cent. of which is black and red, and the remainder white. The average weight of an Angora goat fleece is from 5 to 6 ℔. The finest quality of wool is obtained from the first clip, which is made in the second year of the animal. She-goats yield the best wool, after which come wethers, while the rams give the coarsest fleeces. Angora mohair is a brilliant white lustrous fibre, elastic and wiry in character, and devoid of felting properties. It attains the length of four or five inches, but the long fibre is mixed with an undergrowth of shorter wool, which in the spinning process is combed out as "noils" for separate use. It is a material of enormous durability, and, owing to its remarkable elasticity, it is especially fitted for working into long piled fabrics, such as plush and imitation furs, or for use in braids and bindings, and in boot and other laces. It is largely used for making Utrecht velvet or furniture plush for the upholstering of railway carriages, &c., a trade centred at Amiens. In the making of imitation sealskins, and imitation beaver, otter, chinchilla, and other furs, and for carriage rugs generally, mohair is extensively employed. Many dress fabrics of mixed mohair and alpaca, cotton, or silk are also manufactured; but with changes in fashion such materials are constantly changing in style, composition, and name. Mohair is also used for making certain qualities of lace, and an imitation of ostrich feathers for use as trimming has been made from the fibre. The imports of mohair into the United Kingdom during 1882 amounted to 16,859,771 ℔, valued at £1,433,584, a quantity largely in excess of the imports of any previous year.


MOHAMMEDAN EMPIRE
English Miles
Conquests under Mohammed
Conquests under the first three Caliphs
Farthest limits of the Saracen conquests
Longitude East of Greenwich
SEA OF THE KHIZARS
SEA OF KOLZOM
Sicily
Crete
Cyprus
Oman
YEMEN
ARMENIA
Kohistan
KIRMAN
MEKRAN
Baghdad
Damascus
Medina
Mecca
Samarkand
Bokhara
Merv
Herat
Balkh
Basra
Mosul
Halab
Iskandariya
Barka
Yamama
Nejran
Bahrain
Sijistan
Shiraz
Ispahan
Hamadan
Tabuk
Kairawan
Mahdiya
Tarabolos
MESOPOTAMIA, 'IRÂK, AND SYRIA
English Miles
PERSIAN GULF
Cyprus
Ladikiya
Antakiya
Hama
Hims
Tadmor
Damascus
Sur
Akka
Ghazza
Jerusalem
Edessa
Harran
Rakka
Mosul
Tekrit
Hadîtha
Kerbela
Kadisiya
Ctesiphon (Madain)
Babylon
Basra
Kufa
Euphrates
Tigris
Kerkisiya (Circesium)
Balis
Dara
Nisibis
Amid
W. & A.K. Johnston

MOHAMMEDANISM

UNDER this head is given the history of Mohammed and his successors to the fall of the Eastern Caliphate, with a sketch of the institutions and civilization of the Moslem empire and an account of the Koran. The later history must be sought under the names of individual countries and dynasties. What falls to be said of the social and religious aspects of Islam in modern times will be given under the two great divisions of SUNNITES and SHÍ'ITES.

PART I.—MOHAMMED AND THE FIRST FOUR CALIPHS.

Plate VIII.

MOHAMMED[1] or MAHOMET, the founder of Islam, first appears in the full light of history with his Flight to Medina (The Hijra), A.D. 622; and this date, not that of his birth, has been fittingly chosen as the epoch of the Moslem Era. The best-attested tradition[2] places his first appearance as a prophet in Mecca some twelve years earlier (*circa* 610). He was then forty years old: the forty must be taken as a round number, but as such is doubtless trustworthy. Thus the birth of Mohammed falls about 570 A.D.: it is said to have fallen in the year when Abrahá, the Abyssinian viceroy of Yemen, made the expedition against Mecca, mentioned in the Koran, when the Arabs first saw the elephant and first suffered from smallpox.[3]

Arabia at the birth of Mohammed.

At the time of Mohammed's birth and youth nothing seemed less likely than that the Arabs should presently make their triumphal entrance into the history of the world as victors over the Greeks and Persians. Nowhere in the Peninsula was there an independent state of any considerable power and importance. At the beginning of the 6th century indeed the princes of Kinda had attempted to form a national kingdom, uniting in particular the tribes of central Arabia; but this kingdom was nothing more than an epic prelude to the true history of the Arabs, which begins with Islam. After the fall of the Kindite dynasty, the old anarchy reigned again among the nomads of the Nejd and the Ḥijáz; in all other quarters Greek or Persian influence predominated, extending from the frontier deep into the interior by the aid of two vassal states—the kingdom of the Ghassanids in the Ḥaurán under Greek suzerainty, and that of the Lakhmids in Ḥíra and Anbár under the Persian empire. The antagonism between Byzantium and Ctesiphon was reflected in the feuds of these Arab lordships; but indeed the rivalry of Greek and Persian exercised its influence even on the distant South of the Peninsula. Urged on by the Greeks, the Abyssinians had overthrown the Christian-hating realm of the Himyarites, the sunken remnant of the ancient might of the Sabæans (A.D. 526), the Persians had helped a native prince again to expel the Christians (*circa* 570), and since then the Persians had retained a footing in the land. Toward the close of the 6th century, their direct and indirect influence in Arabia greatly surpassed that of the Greeks; and since the Kindites had fallen before the kings of Ḥíra, it extended right through the Nejd into Yemen.[4]

In the Ḥijáz and western Nejd, the district from which Islam and the Arab empire took their beginning, Greeks and Persians, Ghassanids and Lakhmids, had not much influence; the nomad tribes, and the few urban commonwealths that existed there, lived free from foreign interference, after the manner of their fathers. Mohammed's city was Mecca, where the Banú Kinána had formed a settlement round the Ka'ba, the sanctuary of a number of confederate tribes (Aḥábísh) belonging to that district. The feast annually observed in the days before the full moon of the month Dhú 'l-Ḥijja at Mecca and at 'Arafa and Ḳozaḥ in the vicinity, presented strong attractions for all inhabitants of the Ḥijáz, and grew into a great fair, at which the Meccans sold to the Bedouins the goods they imported from Syria. Feast and fair gave the city the prosperity which it shared with other cities which, like Mecca, had the advantage of lying near the meeting-place of the two great natural roads to Yemen—that from the north-west along the Red Sea coast, and that from the north-east following the line of the mountains that traverse the Nejd.[5] Mecca.

By their trading journeys the Ḳoraish[6] had acquired a knowledge of the world, especially of the Græco-Syrian world: the relative superiority of their culture raised them not only above the Bedouins, but above the agricultural population of such a city as Medina; the art of reading and writing was pretty widely diffused among them. The Ḳoraish within the city were the Banú Ka'b ibn Loay, those in the surrounding country Banú 'Amir ibn Loay; the townsmen proper were again subdivided into Moṭayyabún and Aḥláf—the latter were the new citizens, who were distinguished from the old settlers by the same name in other Arabian towns, as in Ṭáif and Ḥíra. The community was a mere confederation of neighbouring septs, each occupying its own quarter; there was no magistracy, the town as such had no authority. All political action centred in the several septs and their heads; if they held together against outsiders, this was due to interest and a sense of honour, a voluntary union strengthened by the presence of public opinion. In the time of Mohammed, the most numerous and wealthy sept was that of the Banú Makhzúm; but that of the Banú 'Abdshams was the most distinguished. The Banú Omayya were the most powerful house of 'Abdshams; their head, Abú Sofyán ibn Ḥarb, exercised a decisive influence in the concerns of the whole community. Mohammed himself was of the Banú Háshim; it is affirmed that these had formerly enjoyed and claimed of right the position actually enjoyed by the Banú Omayya, but this assertion seems to have had its origin in the claims to the Caliphate which the Hashimites (the house of 'Alí and the 'Abbásids) subsequently set up against the Omayyads.[7]

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[1] The name Mohammad means in Arabic "the praised," and it has been supposed that this epithet was conferred on the Prophet after his mission to mark him out as the promised Paraclete. This, however, is incorrect (Nöldeke, *Gesch. d. Qorans* [Gött. 1860], p. 6, note 2; Sprenger, *Leben und Lehre des M.*, i. 155 *sq.*) The name is found, although it was not common, among the heathen Arabs. Renan has shown it to occur on a Greek inscription of the early part of the 2d century of the Christian era (Boeckh, *C. I. G.*, 4500), and Mohammed ibn Maslama of Medina, a contemporary of the Prophet, bore it as his original name, as appears from the fact that his brother was called Maḥmúd, it being a favourite practice to give to brothers variations of the same name, as Anas and Múnis, Sahl and Sohail, Monabbih and Nobaih (Sprenger, i. 158, note 2). That Mohammed calls himself Aḥmad, in sur. lxi. 6, in order to adapt his name to a supposed prophecy, proves nothing; on the other hand, the men of Mecca, on occasion of a treaty with the Moslems, demanded that the Prophet should not call himself messenger of God, but Moḥammed ibn 'Abdalláh, using his old familiar name; see J. Wellhausen, *Vakidi's Kitāb al-Maghazi in verkürzter deutscher Wiedergabe* (Berl. 1882), p. 257.

[2] Nöldeke, *ut supra*, p. 54 *sq.*

[3] Nöldeke, *Gesch. d. Perser und Araber zur Zeit der Sasaniden aus . . . Tabari übersetzt* (Leyden, 1879), pp. 205, 218.

[4] On the state of Arabia before Islam see Caussin de Perceval, *Essai sur l'histoire des Arabes*, vol. ii.; Muir, *Life of Mah.*, vol. i.

[5] Marr al-Ẓahrán, near Mecca, is accordingly said to have been the point at which the great emigration of tribes from Yemen parted into two streams, moving north-west and north-east respectively.

[6] The Koraish were the branch of Kinána settled in and about Mecca. They are called also Ghálib and Fihr, but the last name is particularly applied to those of the Ḳoraish who did not live within the town.

[7] Sprenger, vol. iii. p. cxx. *sq.*

Youth of the Prophet.

Mohammed's father, ʿAbdallâh b. ʿAbdalmottalib, did not live to see the son's birth, and his mother Âmina died while he was still a child. Mohammed was then cared for first by his grandfather, ʿAbdalmottalib, and after his death by his oldest paternal uncle, Abû Ṭâlib b. ʿAbdalmottalib. He was kindly treated, but shared the hardships of a numerous and very poor family; he herded sheep and gathered wild berries in the desert. This is all that we know of his youth (sur. xciii. 6), all else is legend, containing at most an occasional fragment of truth.[1]

It was, we are told, in his twenty-fifth year that Mohammed, on the recommendation of his uncle, entered the house and business of a wealthy widow named Khadîja. For her he made commercial journeys, thus learning to know part of Palestine and Syria, and perhaps receiving impressions which fructified in his soul.[2] By and by he married the widow, who was much his senior; he was a shrewd man, with prepossessing countenance, fair of skin, and black-haired. The marriage was happy, and blessed with several children. The two sons, however, died young; from the elder the father received the surname Abû 'l-Kâsim. The most famous of the daughters was Fâtima, who married her father's cousin, ʿAlî b. Abî Ṭâlib.

Arabian religion.

During his married life with Khadîja, Mohammed came in contact with a religious movement which had laid hold on some thoughtful minds in Medina, Mecca, and Ṭâif. In Mecca, as elsewhere, Arabian heathenism was a traditional form of worship, chiefly concentrated in great feasts at the holy places; it was clung to because it had come down from the fathers. The gods were many; their importance was not due to the attributes ascribed to them, but to their connection with special circles in which they were worshipped. They were the patrons of septs[3] and tribes, and symbolized, so to speak, the holy unity which united the present and past members of these. Above them all stood Allâh, the highest and universal God.[4] By him the holiest oaths were sworn; in his name (*Bismika Allâhummá*) treaties and covenants were sealed; the lower gods were not fit to be invoked in such cases, as they belonged to one party instead of standing over both. The enemy was reminded of Allâh to deter him from inhuman outrage; enemy of Allâh (ʿaduw Allâh, θεοστυγής) was the name of opprobrium for a villain. But, since Allâh ruled over all and imposed duties on all, it was not thought that one could enter into special relations with him. In worship he had the last place, those gods being preferred who represented the interests of a specific circle, and fulfilled the private desires of their worshippers.[5] Neither the fear of Allâh, however, nor reverence for the gods had much influence. The chief practical consequence of the great feasts was the observance of a truce in the holy months, and this in course of time had become mainly an affair of pure practical convenience. In general, the disposition of the heathen Arabs, if it is at all truly reflected in their poetry, was profane in an unusual degree. Wine, the chase, gaming, and love on the one side; vengeance, feuds, robbery, and glory on the other, occupy all the thoughts of the old poets. Their motives to noble deeds are honour and family feeling; they hardly name the gods, much less feel any need of them. The man sets all his trust on himself: he rides alone through the desert, his sword helps him in danger, no God stands by him, he commends his soul to no saint. His reckless egoism may expand to noble self-sacrifice for the family and the tribe; but in this heroism religious impulses have no part, there is nothing mystical in these hard, clear, and yet so passionate natures. The only vein of what can in any sense be called religious feeling appears when the volcano has burned itself out and the storm of life is over; then, it may be, a wail is heard over the vanity of all the restless activity that is now spent.[6] It is very possible that religion meant more to the sedentary Arabs than to the nomads, to whom almost all the ancient poetry belongs; but the difference cannot have been great. The ancient inhabitants of Mecca practised piety essentially as a trade, just as they do now; their trade depended on the feast, and its fair on the inviolability of the Ḥaram and on the truce of the holy months.[7]

The religion of the Arabs before Mohammed was decrepit and effete.[8] Many anecdotes and verses prove that indifference and scoffing neglect of the gods was nothing uncommon. The need for a substitute for the lost religion was not very widely felt. But there were individuals who were not content with a negation, and sought a better religion. Such were Omayya b. Abî 'l-Ṣalt in Ṭâif, Zaid b. ʿAmr in Mecca, Abû Kais b. Abî Anas, and Abû ʿÂmir in Medina.[9] They were called Ḥanîfs, probably meaning

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[1] The tradition relates that as an infant Mohammed was entrusted to a Bedouin foster-mother, Ḥalîma, who brought him up among her people, the Banû Sa'd b. Laith. Sprenger (i. 162 *sq.*) will have it that this precise statement is also a fiction; but he is probably wrong. It can hardly be disputed that Bedouin women were accustomed to suckle the children of townsfolk for wages, and Mohammed's "milk-kinship" with the Banû Sa'd b. Laith is confirmed by what happened at and after the battle of Ḥonain. A nephew of Mohammed was also brought up among the Sa'd. Comp. *Vakidi, ut supra*, pp. 364, 377 *sq.*, 431, note 1.

[2] He saw the mute witnesses of divine judgment, the rock-dwellings of Ḥijr and the Dead Sea; perhaps, too, he was impressed by the figure of some venerable monk (Bahîra legends). Comp. Ibn Hishâm, p. 115 *sq.*; Sprenger, i. p. 178 *sqq.*

[3] *Vakidi*, p. 350: Idols were found in every house, and homage was paid to them when men went out or in to gain their blessing. Abû Bajrât made and sold them; there was a lively trade in idols with the Bedouins.

[4] The particular gods are said to have been regarded as children of Allâh (בני אלהים). From sur. liii. 21, xxxvii. 149, it appears that the Meccans called their goddesses daughters of Allâh; perhaps it was their disputes with Mohammed that forced them to this view. At first, certainly, al-Lât and al-'Ozzá were names of the wife of the supreme god; sexual dualism dominated in the oldest Arab idea of the godhead. It was Mohammed who first reduced the gods to Jinns—*i.e.* to subordinate demons and kobolds—as he did not deny their existence, but only stripped off their divinity. To say that the oldest Arabs worshipped Jinns is as unreasonable as to say that they worshipped the devil; for Islam degraded the gods to Shaitâns as well as to Jinns. Superstition certainly played its part among the Arabs, but superstition is not religion.

[5] *Vakidi*, pp. 368, note 1, 370, note 1; Sprenger, iii. 457 *sq.*, 512. Whether the feast at Mecca was celebrated in honour of Allâh before Mohammed, is very doubtful. It would seem that Hobal was worshipped in the Ka'ba (Ibn Hishâm, p. 97 *sq.*), and Kozah in Mozdalifa (*Vakidi*, p. 428); it is possible, however, that Allâh stood to Hobal among the Arabs as El to Jahwè among the Hebrews. Ritual sacrifices were generally presented to a god who had a proper name; but the trace of a religious rite which still survived in the ordinary killing of beasts for food, possibly consisted even before Mohammed in the invocation of the name of Allâh (Sprenger, ii. 478, note 1; but comp. *Vakidi*, p. 160, note 1, p. 158).

[6] "We hasten towards an unknown goal, and forget it in eating and drinking. We are sparrows and flies and worms, but more daring than famishing wolves. . . . My roots reach down to the depths of the earth; but this Death spoils me of my youth, and of my soul he spoils me and of my body, and right soon he lays me in the dust. I have urged my camel through every desert, wide-stretching and shimmering with mirage; and I have ridden in the devouring host, reaching after the honours of greedy perils, and I joined in the fray under every sky till I longed for the home-coming instead of booty. But can I, after Ḥarith's death, and after the death of Ḥojr, the noble host—can I hope for a softer lot from the change of time, which does not forget the hard mountains? I know that I must soon be transfixed by his talon and tooth as befell my father and my grandsire, not to forget him that was slain at Kolâb."—Amraalḳais, ed. Slane, No. 10, p. 33; ed. Ahlwardt, No. 5.

[7] See, on Arabian heathenism, Pococke, *Specimen hist. Arabum*; Krehl, *Religion der vorislamischen Araber* (Leip. 1863); Sprenger, i. 241 *sq.* [8] *Vakidi*, p. 293, note 1.

[9] See, for Omayya, *Kitâb ul-Aghânî* (Bûlâk ed.), iii. 186 *sq.*; for Zaid, Ibn Hishâm, p. 143 *sq.*; for Abû Kais, *id.* 348 *sq.*, 39 *sq.*; and for Abû 'Âmir, *Vakidi*, pp. 103, 161, 190, 410.

"penitents", men who strive to free themselves from sin.[1] They did not constitute a regular sect, and had in fact no fixed and organized views. They had, no doubt, intercourse with one another, but were not a close society; they thought more of their own souls than of propaganda; only in Medina they seem to have been more numerous. They rejected polytheism and acknowledged Alláh, but not so much on intellectual grounds as on grounds of conscience. Faith in the one God was with them identical with pious resignation (*Islám*) to his will; their monotheism was most closely allied to the sense of responsibility and of a coming judgment; it stood opposed to the worldly ideas of the idolaters, and was an impulse to upright and sin-avoiding walk. They were not theorists, but ascetics. It was the primitive ideas of Law and Gospel ("the religion of Abraham") that lived again in them. They felt on the whole less attracted towards the developed forms of the religion of revelation; they rather sought after some new form; few of them attached themselves to existing religious communities.

Mohammed, it would appear, came into connexion with these Ḥanífs through a cousin of his wife, Waraḳa b. Naufal, who was one of them. Their doctrines found a fruitful soil in his heart; he was seized with a profound sense of dependence on the omnipresent and omnipotent Lord, and of responsibility towards him. Following the example of old Zaid b. 'Amr, he now frequently withdrew for considerable periods to the solitude of the bare and desolate Mount Ḥirá, and meditated there with prayer and ascetic exercises. For years, perhaps, he went on in these purely individual exercises, without anything to distinguish him essentially from the others who held similar views. But in him the Ḥanífite ideas lodged themselves in a natural temperament which had a sickly tendency to excitement and vision, and so produced a fermentation that ended in an explosion.[2] Thus he became a prophet; he felt himself constrained to leave the silent circle of ascetics and make a propaganda for the truth. In this resolve he was unquestionably influenced by what he knew of the example of the Biblical prophets, perhaps also by the circumstance that a longing after a new founder of religion was diffused among the Ḥanífs, and found support in some dim acquaintance with the Messianic hopes of the Jews.

Jewish and Christian influence.

That Mohammed did not independently produce his own ideas is indisputable; nor is it to be doubted that he derived them from the Ḥanífs. But what was the ultimate source of these first motions towards Islam? In general they are ascribed to a Jewish source. Jews were very numerous in Ḥijáz and Yemen, and had perfectly free intercourse with the Arabs, to whom they undoubtedly imparted a quantity of Biblical and religious material. Mohammed in particular was indebted to the Jews for almost all the stories and a great part of the laws of the Koran (laws of marriage, purity, etc.), and the theological language of Islam is full of Jewish words. But the original and productive forces of Islam did not spring from Judaism, least of all the ideas of the Judgment and of the inexorable demands set before the creature by his Creator, which are so dominant in the older súras. A distinction must be drawn between the primitive impulses and the material added later; Mohammed did not get his leaven from the Jews, they only supplied him afterwards with meal. Neither in truth can Christianity be viewed as the proper source of Islam—Christianity, that is, in any of its great historical developments. The Arabs knew Greek, Syrian, and Abyssinian-Himyaritic churches; manifold influences from these doubtless reached Islam, but in none of them did the idea of Judgment still stand as the central point of religion; the living sense of divine reality ruling over the life was half extinguished by the developments of theology. But in the Syro-Babylonian desert, off the line of the church's main advance, primitive forms of Christianity, perhaps also of Essenism, still survived, which the course of church history had left untouched. To these belong on the one hand the Sabians ("Baptists," from צבע), on the other the numerous anchorets of these regions. The connection of Islam with the Sabians appears from the fact that in Mecca and Ṭáif its adherents were simply known as Sabians.[3] From them, however, were derived, it would seem, for the most part only externals, though the importance of these must on no account be undervalued. The deepest influence exercised on the Ḥanífs, and through them on the Prophet, appears to have come from the anchorite ascetics. How popular they were with the Arabs, appears from the Bedouin poetry; what power they exercised over the minds even of the heathen, is proved by various episodes in the history of Ghassán and Ḥíra; how well the Arabs knew the difference between them and the shaven clergy, is seen in the instructions of Abúbekr to the commanders in the Syrian campaigns. It was not their doctrine that proved impressive, but the genuine earnestness of their consecrated life, spent in preparation for the life to come, for the day of judgment, and forming the sharpest contrast to the profanity of heathenism. Ascesis and meditation were the chief points with the Ḥanífs also, and they are sometimes called by the same name with the Christian monks.[4] It can hardly be wrong to conclude that these nameless witnesses of the Gospel, unmentioned in church history, scattered the seed from which sprang the germ of Islam.

Mohammed's first vision.

The tradition gives a telling story of the way in which Mohammed at length came to proclaim openly what had long been living and working within him; in other words, how he became a prophet. Once, in the month of Ramadan, while he repeated his pious exercises and meditations on Mount Ḥirá, the angel Gabriel came to him by night as he slept, held a silken scroll before him and compelled him, though he could not read, to recite what stood written on it.[5] This was the first descent of a passage of the heavenly book, the source of revelation from which Moses and Jesus and all prophets had drawn; and so Mohammed was called to be a prophet. The words with which Gabriel had summoned him to read, remained graven on his heart. They were the beginning of sur. xcvi.—

[1] Sprenger (p. 38 *sq.*) connects Ḥaníf with חָנֵף, and expounds it per antiphrasin as *lucus a non lucendo*, on the ingenious fashion of A. Geiger. As *taḥannuth* = *taḥannuf* is the technical name of such solitary ascetic practices as Mohammed himself engaged in before his call, Ḥaníf may be taken to mean a *mutaḥannif* by profession. The connexion between *ḥaníf* and *taḥannuf* is certain, and it seems equally certain that *taḥannuf* as an equivalent of *taḥannuth* comes not from *ḥaníf* but from *ḥinth* (for *ḥinf*), and means not to play the Ḥaníf but to concern oneself with one's sin, to purge oneself of it.

[2] It is disputed whether Mohammed was epileptic, cataleptic, hysteric, or what not; Sprenger seems to think that the answer to this medical question is the key to the whole problem of Islam. It is certain that he had a tendency to see visions, and suffered from fits which threw him for a time into a swoon, without loss of inner consciousness.

[3] Ibn Hishám (p. 835) relates that the Banú Jadhíma announced their conversion to Islam to Khálid in the words, "We are become Sabians." Renan, *Études d'histoire rel.* (1863), p. 257, misunderstands this utterance.

[4] Abú 'Amir is as often called Ráhib as Ḥaníf. All the accounts indicate that the Ḥanífs stood nearer to Christianity than to Judaism, not only in Ṭáif but elsewhere. Interesting in the highest degree is a verse ascribed to Ṣakhr al-Ghay in the Hodhailian Poems, ed. Kosegarten 18, 11. A thundercloud is there described, the centre of which is an impenetrable mass; only on the outer fringe a restless motion is discernible. "Its fringes on the mountain-ridge (al-Malá) are like Christians celebrating a banquet when they have found a Ḥaníf (and so run to and fro in the restlessness of glad excitement)."

[5] Of course any one can read in a vision. The question discussed even by Moslems, as to whether the Prophet could read or not, has at least no place in this connexion.

"Read! in the name of thy Lord, who created, created man from a drop. Read! for thy Lord is the Most High who hath taught by the pen, hath taught to man what he knew not. Nay truly man walketh in delusion, when he deems that he suffices for himself; to thy Lord they must all return."

What is here recorded is the commencement, not of Mohammed's knowledge, but of his prophesying. That the latter was due to a vision experienced by him on a night of the month Ramadan (sur. xcvii. 1, ii. 181) is certain, and it is at least very possible that the form of the vision was governed by the traditional conception of revelation and prophecy which Mohammed had learned to accept.[1] It is, of course, uncertain whether the words in which the angel called the Prophet are really contained in sur. xcvi. Certainly this súra is very early, and its contents are, indeed, the best expression of the original ideas of Islam. Man lives on content with himself, but he must one day return to his Creator and Lord, and give account to him. This is in a sense the material principle of the oldest faith of Islam; the formal principle is the very prominent doctrine of revelation in writing copied from the heavenly book.

When the angel left him—so the tradition runs on—Mohammed came to Khadija and recounted the occurrence to her in much distress; he thought that he was possessed. She however comforted him, and confirmed him in the belief that he had received a revelation and was called as a messenger of God. Yet his doubts returned, when there ensued a break in the revelation, and they reached a distressing height. He was often on the point of seeking death by casting himself down from Mount Hirá. It is usually assumed that this state of anguish lasted from two to three years. Then the angel is said to have suddenly appeared a second time; he came to Khadija in great excitement and said: "Wrap me up! wrap me up!" This, it must be explained, was done when he fell into one of his swoons; and on this occasion, as often thereafter, the revelation came during an attack. Then was sent down súra lxxiv. beginning with the address—"O thou enveloped one!" Henceforth there was no interruption and no doubt; the revelations followed without break, and the Prophet was assured of his vocation.

The fatra.

That Mohammed did pass through many doubts and much distress before he reached this assurance, may well be believed (sur. xciii. 3); but the systematic development of the doctrine of the *fatra*, or interval of from two to three years between the first and second revelation, belongs to a later stage of tradition. It appears that it was devised to dispose of the controversy whether Mohammed lived as a prophet in Mecca for ten or for twelve years; perhaps, too, it was desired to solve another difficulty—viz., whether sur. xcvi. or sur. lxxiv. was the beginning of the revelation—in a sense that should do some justice to the rival claims of each.[2] The tradition may also have been influenced by the circumstance that Mohammed, in the first three years of his mission, did not appear as a public preacher,[3] but only sought recruits for his own cause and the cause of Alláh in private circles. First, he gained the inmates of his own house,—his wife Khadija, his freedman Zaid b. Haritha, his cousin 'Alí (of whose nurture he had relieved Abú Tálib, a poor man with many children), and finally his dearest friend Abúbekr b. Abi Kohâfa. The last named won for him several other adherents: 'Othmán b. 'Affán, Zobair b. al-'Awwám, 'Abd al-Rahmán b. 'Auf, Sa'd b. Abi Wakkás, Talha b. 'Obaid Alláh, all names of note in the subsequent history of Islam. Soon there was a little community formed, whose members united in common exercises of prayer.

To the Hanifs, especially to the family of Zaid b. 'Amr, their relation was friendly; they had the name of Moslem in common, and there was hardly any difference of principle to separate them. The personality of the prophet had given an altogether new impulse to a movement already in existence; that was all. To found a new religion was in no sense Mohammed's intention; what he sought was to secure among his people the recognition of the old and the true. He preached it to the Arabs as Moses had before him preached to the Jews, and Jesus to Christians; it was all one and the same religion as written in the heavenly book. The differences between the several religions of the book were not perceived by him till a much later period.

It is not difficult to understand why Mohammed should in the first instance have turned to those who were most readily accessible to him; but the nature of his mission did not suffer him to rest content with this; it compelled him to make public proclamation of the truth. One of his dependents, Arkam b. Abi Arkam, offered for this purpose his house, which stood close by the sanctuary, and thus the Moslems obtained a convenient meeting-place within the town, instead of, as hitherto, being compelled to resort to ravines and solitary places.[4] Here Mohammed preached, and here too it was that he received some converts to Islam. But he did not obtain any great results among the Meccans. What he had to say was already in substance familiar to them; all that was new was the enthusiasm with which he proclaimed old truth. But this enthusiasm failed to make any impression on them; they set him aside as a visionary, or as a poet, or simply as one possessed. In their eyes it was a fatal flaw that his supporters were drawn from the slave-class and the lower orders, and the ranks of the young; it would have been quite another matter if one of the rulers or elders had believed in him. This circumstance was a source of annoyance to the prophet himself; in sur. lxxx. we find him rebuked by God for having repulsed in an unkind way a blind beggar who had interrupted him as he was endeavouring to win over a man of influence—an endeavour which proved of no avail.

This indifference of the Meccans embittered the messenger of God, and led him to give to his preaching a polemical character which it had not hitherto possessed. In the oldest súras we have monotheism in its positive and practical form.[5] God is the all-powerful Lord and all-knowing Judge of man; he demands loyal self-surrender and unconditional obedience; the service he requires is a serious life, characterized in particular by prayer, almsgiving, and temperance. That the worship of other gods beside Alláh is excluded by these views, goes without saying; still it is

[1] H. Dodwell, "De Tabulis cœli," in Fabricius, *Cod. pseud. V. T.*, 2d ed., ii. 551 *sq.* Compare, in the Koran, especially sur. lxxxvii. 6, "We will cause thee so to read that thou mayest forget nothing save what God will." The *following* progress is noteworthy:—Isaiah's lips are touched to purge them of sin (Isa. vi. 7); Jeremiah's are touched by the Lord to put His word in his mouth (Jer. i. 9); Ezekiel receives the revelation as a roll of a book which he has to swallow (Ezek. iii. 2).

[2] See Sprenger in *Z.D.M.G.*, 1859, p. 173 *sq.*; Nöldeke, *op. cit.*, 67 *sq.* Ewald thinks that the vocatives at the beginning of sur. lxxiv. and lxxiii. mean simply—*O long sleeper!* This view is worthy of consideration. The Moslem exegetes thoroughly understand the art of giving to general expressions of the Koran specific reference to historical events which they have themselves invented to facilitate exegesis.

[3] Ibn Hishám, p. 166.

[4] It does not appear that Arkam's house was of the nature of an asylum to which Mohammed betook himself for refuge from the ill-treatment to which he was subjected in his own home, nor is there any evidence that he ever lived in it. It was simply the meeting-house of the oldest Islam. Prayer continued to be offered within it until the conversion of 'Omar, who was bold enough to choose the Ka'ba itself, the centre of heathenism, as the Moslem place of prayer. Comp. Muir, ii. p. 117; Sprenger, i. p. 434.

[5] What is meant by practical monotheism is most easily understood by reference to Matt. vi. 24 *sqq.*, x. 28 *sqq.*, and to Luther's exposition of the first commandment in the catechisms; it is the essence of religion. We do not, of course, mean that this practical monotheism is expressed in the Koran with as much purity and depth as in the Gospel.

noteworthy that the sharp negations of monotheism acquired prominence only by degrees. It was in his indignation against the cold mockery with which he was met that Mohammed first assumed an attitude of hostility towards the worship of polytheism, while at the same time he gave much greater prominence to his own mission, just because it was not acknowledged. He now began to threaten the infidels with the judgment of God for their contempt of His message and His messenger; he related to them the terrible punishments that in other cases had fallen on those who refused to hear the voice of their prophet, applying the old legends to the circumstances of the present with such directness that it was superfluous expressly to add the morals.

Hostility of the Meccans.

This could not fail to irritate the Meccans, especially as after all the new religion gained ground. What Mohammed attacked as ungodly and abominable were their holy things; they were jealous for their gods and their fathers. Their attachment to the traditional worship was the greater that the prosperity of their town rested upon it; for they had not yet learned that the Ka'ba was no institution of heathenism. They found, however, no other way to remove the public scandal than to approach Abú Ṭálib, the Prophet's uncle and the head of his family, asking him to impose silence on the offender, or else to withdraw from him his protection. Abú Ṭálib was not personally convinced of Mohammed's mission, but he did not choose to impose conditions on the enjoyment of his protection. At length, however, when the Meccans adopted a threatening tone and said that he must either restrain his nephew from his injurious attacks, or openly take side for Mohammed and against them, he sent for his nephew, told him how things stood, and urged him not to involve them both in ruin. Mohammed was deeply moved; he thought his uncle wished to get rid of him; yet he could not and would not withdraw from the divinely-imposed necessity which impelled him to preach his convictions. "Though they gave me the sun in my right hand," he said, "and the moon in my left, to bring me back from my undertaking, yet will I not pause till the Lord carry my cause to victory, or till I die for it." With this he burst into tears, and turned to go away. But Abú Ṭálib called him back and said: "Go in peace, son of my brother, and say what thou wilt, for, by God, I will on no condition abandon thee."

The protection of his uncle did not relieve Mohammed from all manner of petty insults which he had to endure from his enemies from day to day; but no one ventured to do him serious harm, for the family feud which this would necessarily have produced was not to be lightly incurred. Less fortunate than the Prophet, however, were such of his followers as occupied dependent positions, and had no family support; especially the converted bondmen and bondwomen, who found no consideration, and were often treated with actual cruelty. For some of these Abúbekr purchased freedom. There seem to have been no martyrs, but the situation of many Moslems became so intolerable that they fled to Abyssinia. The Abyssinian Christians were quite looked upon as their religious kinsmen.

The temporary compromise.

A breach with one's people is for the Arab a breach with God and the world; he feels it like a living death. Mohammed, who remained in Mecca, naturally made every effort to heal the breach with his townsmen, and, as naturally, the latter met him half-way. He even went so far as to take the edge from his monotheism. Once, when the heads of the Koraish were assembled at the Ka'ba, Mohammed, we are told, came to them and began to recite before them sur. liii.[1] When he came to the passage, "What think ye of al-Lát and al-'Ozzá, and of Manát the third with them?" the devil put words in his mouth which he had long wished to have by revelation from God—viz. "These are the sublime Cranes,[2] whose intercession may be hoped for." The auditors were surprised and delighted by this recognition of their goddesses, and when Mohammed closed the súra with the words, "So prostrate yourselves before Alláh and do service to him," they all with one accord complied. They then professed their satisfaction with his admissions, and declared themselves ready to recognize him. But the messenger of God went home disquieted. In the evening Gabriel came to him, and Mohammed repeated to him the súra; whereupon the angel said: "What hast thou done? thou hast spoken in the ears of the people words that I never gave to thee." Mohammed now fell into deep distress, fearing to be cast out from the sight of God. But the Lord took him back to His grace and raised him up again. He erased the diabolical verse and revealed the true reading, so that the words now ran—"What think ye of al-Lát and al-'Ozzá, and of Manát the third with them? The male [offspring] for you and the female for God? That were an unjust division!" When the new version reached the ears of the Meccans they compared it with the old, and saw that the Prophet had broken the peace again. So their enmity broke out again with fresh violence.

It is generally and justly suspected that this compromise did not rest on a momentary inspiration of Satan, but was the result of negotiations and protracted consideration. Nor was the breach so instantaneous as is represented; the peace lasted more than one day. There is no doubt as to the fact itself. Every religion must make compromises to gain the masses. But for Mohammed the moment for this had not yet arrived; later on he used the method of compromise with great effect.

The news of the peace between Mohammed and the Meccans had recalled the fugitive Moslems from Abyssinia;[3] on their return the actual state of affairs proved very different indeed from what they had been led to expect, and it was not long before a second emigration took place. By degrees as many as a hundred and one Moslems, mostly of the younger men, in little groups, had again migrated to Abyssinia, where they once more met with a friendly reception. Among them were Ja'far, the brother of 'Alí, and the Prophet's daughter Rokayya, along with her husband 'Othmán b. 'Affán.[4]

Mohammed's position was very considerably altered for the worse, both subjectively and in other respects, by his precipitate withdrawal from the compromise almost as soon as it had been made. He himself indeed, although long and salutarily humbled by the remembrance of his fall (sur. xvii. 75 *sqq.*), never abandoned faith in his vocation; his followers also did not permit themselves to be led

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[1] The authorities for this are Ibn Sa'd, the secretary of Wákidí, to whom we owe the preservation of Wákidí's materials for the Meccan period, and especially Ṭabarí; comp. Muir, ii. 150 *sqq.* The common tradition ignores the fact itself, but knows its result, the return of the Abyssinian fugitives.

[2] "*Al-gharánik al-'olá*," fine-sounding but perhaps meaningless words—

"Herrlich, etwas dunkel zwar,
Doch es klingt recht wunderbar."

Comp. Nöldeke, *op. cit.*, p. 80. Hobal, though the chief god of the Meccans, is not mentioned in the Koran either here or elsewhere. Perhaps as God of the Ka'ba he was already identified with Alláh by the Meccans, or was so identified by Mohammed.

[3] The date assigned is the month Rajab of the fifth year of the Call, corresponding to the eighth year before the Flight (A.D. 614-615). The compromise must have been made in the interval. The chronology of this period is of course in the highest degree uncertain, and the order of the events hard to ascertain. Thus it can scarcely be determined whether the above-mentioned scene with Abú Ṭálib ought to be placed before or after the compromise.

[4] 'Othmán and Rokayya, however, members of the noble house of Omayya, soon returned, along with many others. The rest remained in exile until the seventh year of the Flight.

Tradition has it that he found comfort in the fact that at least the Jinns listened to him as by the way he chanted the Koran in the sacred grove of Nakhla.[1] In the present circumstances it was now impossible for him to return into the town, after having openly announced his intention of breaking with it and joining another community. He did not venture to do so until, after lengthened negotiations, he had assured himself of the protection of a leading citizen, Moṭ'im b. 'Adí. Notwithstanding all that had happened, he resolved, two months after the death of Khadíja, to enter upon a second marriage with Sauda bint Zam'a, the widow of an Abyssinian emigrant.

Chance soon afterwards brought to pass what forethought (on his journey to Ṭáif) had failed to accomplish. After having given up the Meccans, Mohammed was wont to seek interviews with the Arabs who came to Mecca, Majanna, Dhú 'l-Majáz, and 'Okáẓ, for the purpose of taking part in the feasts and fairs, and to preach to them.[2] On one such occasion, in the third year before the Flight (A.D. 619-620), he fell in with a small company of citizens of Medina, who to his delight did not ridicule him, as was usually the case, but showed both aptness to understand and willingness to receive his doctrines. For this they had been previously prepared, alike by their daily intercourse with the numerous Jews who lived in confederation with them in their town and neighbourhood, and by the connections which they had with the Nabatæans and Christian Arabs of the north. Ḥanífitism was remarkably widely diffused among them, and at the same time there were movements of expectation of a new religion, perhaps even of an Arabian Messiah, who should found it. Medina was the proper soil for Mohammed's activity. It is singular that he owed such a discovery to accident. He entered into closer relations with the pilgrims who had come from thence, and asked them to try to find out whether there was any likelihood of his being received in their town. They promised to do so, and to let him hear from them in the following year.

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At the pilgrim feast of next year, accordingly, twelve citizens of Medina had a meeting with Mohammed,[3] and gave him their pledge to have no god but Alláh, to withhold their hands from what was not their own, to flee fornication, not to kill new-born infants, to shun slander, and to obey God's messenger as far as was fairly to be asked.[4] This is the so-called First Homage on the 'Aḳaba.[5] The twelve men now returned, as propagandists of Islam, to their homes with the injunction to let their master hear of the success of their efforts at the same place on the following year. One of the Meccan Moslems, Moṣ'ab b. 'Omair, was sent along with or after them, in order to teach the people of Medina to read the Koran, and instruct them in the doctrines and practices of Islam.

Islam spread very quickly on the new soil. It is easy to understand how his joy strengthened the Prophet's spirit to try a higher flight. As a symptom of his exalted frame we might well regard his famous night-journey to Jerusalem (sur. xvii. 1; vi. 2), if we could be sure that it belonged to this period.[6] The prophecy also of the final triumph of the Romans over the Persians (contained in sur. xxx. 1 sqq.) might very well pass for an expression of his own assurance of victory, as at that time he still had a feeling of solidarity with the Christians. But the prophecy (the only one contained in the Koran) belongs, it would appear, to a much earlier date.[7]

Second Homage.

At the Meccan festival of the last year before the Flight (in March 622) there presented themselves among the pilgrims from Medina seventy-three men and two women who had been converted to Islam. In the night after the day of the sacrifice they again had an interview with the Prophet on the 'Aḳaba; Al-'Abbás, his uncle, who after Abú Ṭálib's death had become head of the Banú Háshim, was also present. This is the so-called Second Homage on the 'Aḳaba, at which Mohammed's emigration to Medina was definitely settled. Al-'Abbás solemnly transferred his nephew from under his own protection to that of the men from Medina, after these had promised a faithful discharge of the duties this involved. They swore to the Prophet to guard him against all that they guarded their wives and children from. He, on the other hand, promised thenceforward to consider himself wholly as one of themselves, and to adhere to their society. According to the tradition this remarkable scene was brought to a close by a sudden noise.

The emigration.

The Meccans soon got wind of the affair, notwithstanding the secrecy with which it had been gone about, but Ibn Obay, the leader of the Medina pilgrim caravan, whom they questioned next morning, was able with good conscience to declare that he knew nothing at all about it, as, being still a heathen, he had not been taken into the confidence of his Moslem comrades, and he had not observed their absence over night. The Meccans did not gain certainty as to what had occurred, until the men of Medina had left. They set out after them, but by this they gained nothing. They next tried, it is said, violently to prevent their own Moslems from migrating. After a considerable pause, they renewed the persecution of the adherents of the Prophet, compelling some to apostasy, and shutting up others in prison. But the measures they adopted were in no case effective, and at best served only to precipitate the crisis. A few days after the homage on the 'Aḳaba, Mohammed issued to his followers the formal command to emigrate. In the first month of the first year of the Flight (April 622) the emigration began; within two months some 150 persons had reached Medina. Apart from slaves, only a few were kept behind in Mecca.[8]

Mohammed himself remained to the last in Mecca, in the company of Abúbekr and 'Alí. His reason for doing so is as obscure as the cause of his sudden flight. The explanation offered of the latter is a plan laid by the Meccans for his assassination, in consequence of which he secretly withdrew along with Abúbekr. For two or three days the two friends hid themselves in a cave of Mount Thaur, south from Mecca, till the pursuit should have passed over (sur. ix. 40). They then took the northward road and arrived safely in Medina on the 12th of Rabí' of the first year of the Flight.[9] Meanwhile, 'Alí remained three

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Law. Mohammed thus laid the foundations of his position in a manner precisely similar to that which Moses (Exod. xviii.) is said to have followed; and just as the Torah grew out of the decisions of Moses, so did the Sunna out of those of Mohammed. It was perhaps in judicial and regulative activity, which he continued quietly to carry on to the very end of his life, that his vocation chiefly lay. At all events his work in this direction was extremely beneficial, if only because he was the creator of law and justice where previously there had been nothing but violence, self-help, or at best voluntary arrangement. But the contents of his legislation also (if it can be called by such a name) marked a distinct advance upon what had been the previous use and wont in Arabia. In particular, he made it his special care to set a fence round the rights of property, and to protect and raise the place of woman in marriage. Blood revenge he retained indeed, but completely altered its character by reserving to himself the right of permitting it; in other words, the right of capital sentence. It need not be said that in many ways he availed himself of that which already existed, whether in the form of Arab usage or of Jewish law; he followed the latter, in particular, in his laws relating to marriage.

Religion. The new situation of affairs inevitably brought it about that religion was made a mere servant in the work of forming a commonwealth. Never has this service been better performed; never has it been utilized with greater adroitness as a means towards this end. In Mecca, Islam had originally been nothing more than the individual conviction of Mohammed; it was only after severe struggles that he went so far as to preach it, and even his preaching had no other aim than to create individual conviction in others. What he said was of the simplest description—that people ought to believe in God and in judgment to come, that men ought to live their lives seriously and not waste them in follies, that one ought not to be high-minded or covetous, and so on. A community arose, it is true, even in Mecca, and was confirmed by the persecutions. There also religious meetings were held and social prayers. But everything was still in a very fluid and rudimentary stage; religion retained its inward character. It was not until the first two years after the Flight that it gradually lost this, and became, if not exclusively, yet to a very large extent, a mere drill system for the community.[1] No god but the one God (lá iláh illa 'lláh) was the entire sum of their dogmatic, and less importance was attached to belief in it than to profession of it. It was the watchword and battle-cry. The prayers[2] took the form of military exercises; they were imitated with the greatest precision by the congregation, after the example of the Imám. The mosque was, in fact, the great exercising ground of Islam; it was there that the Moslems acquired the *esprit de corps* and rigid discipline which distinguished their armies.

Next to the monotheistic confession (tauḥíd) and to prayer (ṣalát) came almsgiving (zakát, ṣadaḳa) as a third important means by which Mohammed awakened and brought into action among his followers the feeling of fellowship. The alms by and by grew to be a sort of tithe, which afterwards became the basis of the Moslem fiscal system, and so at the same time the material foundation of the Moslem state. Religion received so practical a development that of alms nothing but the name remained, and the convenient fiction that the taxes had to be paid to God.

Increased exclusiveness. Just in proportion to the closeness of the union into which Islam brought its followers did its exclusiveness towards them that were without increase. If in Mecca Mohammed in his relations to the other monotheistic religions had observed the principle, "he that is not against me is for me," in Medina his rule was "he that is not for me is against me." As circumstances were, he had to adjust matters chiefly with the Jews. Without any intention on their part, they had helped to prepare the ground for him in Medina; he had great hopes from them, and at first treated them on no different footing from that of the Arab families which recognized him. But as his relations with the Aus and Khazraj consolidated, those which he had with the Jews became less close. The conjunction of religious with political authority, the development of civil polity out of religion, of the kingship from the prophetic function, was precisely what they objected to.[3] On the other hand, while the old polity of Medina, broken up and disorganized as it was, had no difficulty in tolerating foreign elements within its limits, the new political system created by Islam changed the situation, and rendered it necessary that these should be either assimilated or expelled.

The Jews. Mohammed's hostility to the Jews found expression, in the first instance, theoretically more than practically,[4] and especially in the care with which he now differentiated certain important religious usages which he had taken over from Judaism, so that they became distinguishing marks between Islam and Mosaism. Thus, for example, he altered the direction of prayer (Kibla), which formerly used to be towards Jerusalem, so that it now was towards Mecca; and for the fast on the 10th of Tisri ('Ashúrá) he substituted that of the month of Ramaḍan.[5] In appointing Friday as the principal day of public worship, he may also possibly have had some polemical reference to the Jewish Sabbath. Of these alterations the greatest in positive importance is the transference of the Kibla to Mecca. It symbolizes the completion of the Arabizing process which went on step by step with the change Islam underwent from being an individual to being a political religion. In substituting the Meccan Ka'ba for the sanctuary at Jerusalem, Mohammed did not merely bid farewell to Judaism and assert his independence of it; what he chiefly did was to make a concession to heathenism, and bring about a nationalization of Islam, for the purpose of welding together the Arab tribes (Kabáil) into one community. Of similar significance was the institution of the feast of sacrifice ('íd al-doḥá) on the day of the Meccan festival. The Moslems were to observe the latter as much as possible, even if they could not be actually present on the spot.

Precepts of Islam. Thus we have the five chief precepts of Islam—(1) Confession of the unity of God; (2) stated prayer; (3) almsgiving; (4) the fast of Ramaḍan; (5) observance of the festival of Mecca. Capable of having deeper meanings

[1] This is to be understood as applying to the system as a whole. Of course, there are always individuals who break through system; but the historical power of Islam rests upon the system. To the system also belongs the spiritual jargon which Mohammed introduced. It was no longer permissible to say "Good morning!" ('im ṣabáḥan), the phrase now ran, "Peace be with thee!" and on every occasion pious forms of speech were demanded. Characteristic of the puritanism of the system is the prohibition of wine and of gaming, first issued in the years immediately following the Flight, and the contempt for poetry.

[2] They were five in number—at sunrise, noon, afternoon, sunset, and late evening. Each prayer consisted originally of two, afterwards of four, prostrations. The chief weekly public service (jom'a), with sermon, was held on Friday at mid-day.

[3] While Islam had the effect of uniting the Arabs politically, uniformity of religion in the case of the Jews had no such effect; on the contrary, the mutual feuds and hatreds in which they indulged conduced greatly to the advantage of the Moslems. The Jews, of course, recognised Mohammed's supremacy as a fact, but they denied any legal title thereto as arising from his prophetic office.

[4] Compare the well-known second súra, in which a long attack is made on Judaism.

[5] A connection with the Christian fasts is usually alleged. It is possible that Christian influence may have to do with the long duration of the fasts, but it cannot have anything to do with the selection of Ramaḍan; for in the first years after the Flight, Ramaḍan fell not in Spring but in December.

Law. Mohammed thus laid the foundations of his position in a manner precisely similar to that which Moses (Exod. xviii.) is said to have followed; and just as the Torah grew out of the decisions of Moses, so did the Sunna out of those of Mohammed. It was perhaps in judicial and regulative activity, which he continued quietly to carry on to the very end of his life, that his vocation chiefly lay. At all events his work in this direction was extremely beneficial, if only because he was the creator of law and justice where previously there had been nothing but violence, self-help, or at best voluntary arrangement. But the contents of his legislation also (if it can be called by such a name) marked a distinct advance upon what had been the previous use and wont in Arabia. In particular, he made it his special care to set a fence round the rights of property, and to protect and raise the place of woman in marriage. Blood revenge he retained indeed, but completely altered its character by reserving to himself the right of permitting it; in other words, the right of capital sentence. It need not be said that in many ways he availed himself of that which already existed, whether in the form of Arab usage or of Jewish law; he followed the latter, in particular, in his laws relating to marriage.

Religion. The new situation of affairs inevitably brought it about that religion was made a mere servant in the work of forming a commonwealth. Never has this service been better performed; never has it been utilized with greater adroitness as a means towards this end. In Mecca, Islam had originally been nothing more than the individual conviction of Mohammed; it was only after severe struggles that he went so far as to preach it, and even his preaching had no other aim than to create individual conviction in others. What he said was of the simplest description—that people ought to believe in God and in judgment to come, that men ought to live their lives seriously and not waste them in follies, that one ought not to be high-minded or covetous, and so on. A community arose, it is true, even in Mecca, and was confirmed by the persecutions. There also religious meetings were held and social prayers. But everything was still in a very fluid and rudimentary stage; religion retained its inward character. It was not until the first two years after the Flight that it gradually lost this, and became, if not exclusively, yet to a very large extent, a mere drill system for the community.[1] No god but the one God (lá iláh illa 'lláh) was the entire sum of their dogmatic, and less importance was attached to belief in it than to profession of it. It was the watchword and battle-cry. The prayers[2] took the form of military exercises; they were imitated with the greatest precision by the congregation, after the example of the Imám. The mosque was, in fact, the great exercising ground of Islam; it was there that the Moslems acquired the *esprit de corps* and rigid discipline which distinguished their armies.

Next to the monotheistic confession (tauḥíd) and to prayer (ṣalát) came almsgiving (zakát, ṣadaḳa) as a third important means by which Mohammed awakened and brought into action among his followers the feeling of fellowship. The alms by and by grew to be a sort of tithe, which afterwards became the basis of the Moslem fiscal system, and so at the same time the material foundation of the Moslem state. Religion received so practical a development that of alms nothing but the name remained, and the convenient fiction that the taxes had to be paid to God.

Increased exclusiveness. Just in proportion to the closeness of the union into which Islam brought its followers did its exclusiveness towards them that were without increase. If in Mecca Mohammed in his relations to the other monotheistic religions had observed the principle, "he that is not against me is for me," in Medina his rule was "he that is not for me is against me."

The Jews. As circumstances were, he had to adjust matters chiefly with the Jews. Without any intention on their part, they had helped to prepare the ground for him in Medina; he had great hopes from them, and at first treated them on no different footing from that of the Arab families which recognized him. But as his relations with the Aus and Khazraj consolidated, those which he had with the Jews became less close. The conjunction of religious with political authority, the development of civil polity out of religion, of the kingship from the prophetic function, was precisely what they objected to.[3] On the other hand, while the old polity of Medina, broken up and disorganized as it was, had no difficulty in tolerating foreign elements within its limits, the new political system created by Islam changed the situation, and rendered it necessary that these should be either assimilated or expelled.

Mohammed's hostility to the Jews found expression, in the first instance, theoretically more than practically,[4] and especially in the care with which he now differentiated certain important religious usages which he had taken over from Judaism, so that they became distinguishing marks between Islam and Mosaism. Thus, for example, he altered the direction of prayer (Kibla), which formerly used to be towards Jerusalem, so that it now was towards Mecca; and for the fast on the 10th of Tisri ('Ashúrá) he substituted that of the month of Ramaḍan.[5] In appointing Friday as the principal day of public worship, he may also possibly have had some polemical reference to the Jewish Sabbath. Of these alterations the greatest in positive importance is the transference of the Ḳibla to Mecca. It symbolizes the completion of the Arabizing process which went on step by step with the change Islam underwent from being an individual to being a political religion. In substituting the Meccan Ka'ba for the sanctuary at Jerusalem, Mohammed did not merely bid farewell to Judaism and assert his independence of it; what he chiefly did was to make a concession to heathenism, and bring about a nationalization of Islam, for the purpose of welding together the Arab tribes (Ḳabáil) into one community. Of similar significance was the institution of the feast of sacrifice ('Id al-ḍoḥá) on the day of the Meccan festival. The Moslems were to observe the latter as much as possible, even if they could not be actually present on the spot.

Precepts of Islam. Thus we have the five chief precepts of Islam—(1) Confession of the unity of God; (2) stated prayer; (3) almsgiving; (4) the fast of Ramaḍan; (5) observance of the festival of Mecca. Capable of having deeper meanings

[1] This is to be understood as applying to the system as a whole. Of course, there are always individuals who break through system; but the historical power of Islam rests upon the system. To the system also belongs the spiritual jargon which Mohammed introduced. It was no longer permissible to say "Good morning!" ('im sabáhan), the phrase now ran, "Peace be with thee!" and on every occasion pious forms of speech were demanded. Characteristic of the puritanism of the system is the prohibition of wine and of gaming, first issued in the years immediately following the Flight, and the contempt for poetry.

[2] They were five in number—at sunrise, noon, afternoon, sunset, and late evening. Each prayer consisted originally of two, afterwards of four, prostrations. The chief weekly public service (jom'a), with sermon, was held on Friday at mid-day.

[3] While Islam had the effect of uniting the Arabs politically, uniformity of religion in the case of the Jews had no such effect; on the contrary, the mutual feuds and hatreds in which they indulged conduced greatly to the advantage of the Moslems. The Jews, of course, recognised Mohammed's supremacy as a fact, but they denied any legal title thereto as arising from his prophetic office.

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by force to the rebels who showed unwillingness to accept it. More literally than Christ could Mohammed say of himself that he was come not to bring peace but a sword. Islam was a standing declaration of war against idolaters.

The holy war. The nearest object against which to direct the holy war (jihád) was presented by the Meccans. Against them first did Mohammed bring into operation the new principle, that it is faith and not blood that separates and unites. According to Arab notions it was a kind of high treason on his part to leave his native town in order to join a foreign society; on the part of the people of Medina it was an act of hostility to Mecca to receive him among them. The Meccans would have been fully justified on their side in taking arms against the Moslems, but they refrained, being too much at their ease, and shrinking besides from fratricidal war. It was the Moslems who took the initiative; aggressiveness was in their blood. Mohammed began with utilizing the favourable position of Medina, on a mountain spur near the great highway from Yemen to Syria, to intercept the Meccan caravans. Originally he sent forth only the Emigrants to take part in the expeditions, as the people of Medina had pledged themselves to defend him only in the event of his being attacked; soon, however, they also joined him. What first induced them to do so was the prospect of booty; afterwards it was impossible to separate themselves, so great was the fusion of elements which had been quietly going on within the crucible of Islam.

The first plunder was taken in the month Rajab, A.H. 2 (Autumn 623), in which circumstance was at once seen the advantage arising from the change of conscience brought about by the new religion; for in Rajab feuds and plundering raids were held to be unlawful. Relying upon the sacredness of this month a caravan of Koraish was returning from Ṭáif laden with leather, wine, and raisins. But this did not prevent Mohammed from sending out a band of Emigrants to surprise the caravan at Nakhla, between Ṭáif and Mecca; his orders to this effect were given in a document which was not to be unsealed until two days after the departure of the expedition. The plan was carried out, and the surprise was all the more successful, because the robbers gave themselves the outward semblance of pilgrims; one Meccan was killed in the struggle. But the perfidy with which in this instance Mohammed's advanced religious views enabled him to utilize for his own advantage the pious custom of the heathen roused in Medina itself such a storm of disapproval, that he found himself compelled to disavow his own tools. In Mohammedan tradition, the contents of the unambiguous document in which he ordered the surprise are usually falsified.

Battle of Bedr. The Koraish still remained quiet; another outrage had yet to come. In Ramadan A.H. 2 (December 623), the return of their great Syrian caravan was expected, and Mohammed resolved to lie in wait for it at Bedr, a favourite watering-place and camping-ground, northward from Medina. For this purpose he set out thither in person along with 308 men; but the leader of the caravan, the Omayyad Abú Sofyán, got word of the plan and sent a messenger to Mecca with a request for speedy help. Concern about their money and goods at last drove the Koraish to arms; a very short interval found them, 900 strong, on the road to Bedr. By the way they received intelligence that the caravan had made a circuit to the west of Bedr, and was already in safety. Nevertheless they resolved, at the instance of the Makhzumit Abú Jahl, for the sake of their honour, to continue their march. When the Moslems first got touch of them at Bedr, they took them for the caravan; their surprise on discovering the truth may be imagined. But, kept firm by the courage of their leader, they resolved to face the superior numbers of the enemy. On the morning of Friday, the 17th of Ramadan, the encounter took place. A number of duels were fought in the front, which were mostly decided in favour of the Moslems. The Meccans at last gave up the fight, strictly speaking for no other cause than that they did not see any reason for carrying it on. They were reluctant to shed the blood of their kinsmen; they were awestruck in presence of the gloomy determination of their adversaries, who did know what they were fighting for, and were absolutely reckless of consequences. After a number of the noblest and oldest of the Koraish, including at last Abú Jahl, had fallen, those who remained took to flight. The number of the dead is said to have been as great as that of the prisoners. Two of the latter, whom he personally hated, Mohammed caused to be put to death—'Okba b. Abí Mo'ait and al-Nadr b. al-Hárith. When the last named had perceived, from the Prophet's malignant glance, the danger in which he stood, he implored an old friend of his among the Moslems for his intercession. This request being refused, al-Nadr said: "Had the Koraish taken thee prisoner, thou hadst not been put to death as long as I had lived;" to which the apologetic reply was: "I do not doubt it, but I am differently placed from thee, for Islam has made an end of the old relations." To the remaining prisoners life was spared on payment by their kinsmen of a heavy ransom; but Mohammed is said to have afterwards reproached himself for having allowed considerations of earthly gain to keep him back from sending them all to hell as they deserved.

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The War of the Fosse was the last attack made by the Ḳoraish upon Medina; Mohammed now began to take the offensive towards Mecca. This he at first set about with extreme diplomacy, utilizing the festival, and the truce of God subsisting at the time of the festival, for the purpose of paying a visit to his native town. Although unsuccessful in winning to his side the neighbouring tribes of Bedouins, it was nevertheless with a considerable following (1500 men) that in Dhú 'l-ḳa'da A.H. 6 (March 628),[1] he set out on his journey. In a dream he had had the key of the Ka'ba delivered to him; on the strength of this his followers believed firmly in the success of the expedition. But the Ḳoraish were determined that the pretext of pilgrimage should not avail their adversary; they summoned their allies and formed a camp to the north of their town for the purpose of preventing the entrance of the Moslems.

Hodai-biya. Mohammed was forced to halt at Ḥodaibiya on the borders of the sacred territory, and it was in vain that by fair speeches he sought to obtain permission to make the circuit of the Ka'ba. He felt himself too weak to force his way, and accordingly preferred to treat. While the envoys were passing to and fro, there suddenly arose an alarm in the Moslem camp; they apprehended a sudden act of treachery on the part of the Meccans. It was on this occasion that the famous Homage under the Tree took place, when Mohammed pledged his followers by striking hands that they would stand by him and go to death for his sake. Some of the Ḳoraish agents witnessed the scene, and were immensely impressed by it; such an enthusiastic obedience as Mohammed received, such an ascendency over the minds of men as he exercised, they had never before conceived to be possible, and on their return they urged their people in the strongest way not to permit matters to come to extremities. The Ḳoraish accordingly judged it best to offer a bargain with Mohammed, the terms being that for this year he was to withdraw, so that the Arabs might not say that he had forced an entrance, but that on the following year he was to return and be permitted to remain three days within the sacred territory for the purpose of sacrifice. After some discussion Mohammed accepted this proposal, although zealous Moslems detected a discreditable shortcoming in matters of faith, in so far as it involved turning back within sight of the Ka'ba without being allowed to accomplish the sacred circuit. When the agreement was to be committed to writing, Mohammed dictated the words: "In the name of Alláh, the merciful Raḥmán";[2] but the Meccan plenipotentiary, Sohail b. 'Amr, declared that he knew nothing about Raḥmán, and insisted upon the customary formula—"In thy name, Allá-homma!" The Moslems murmured, but Mohammed yielded. He then went on to dictate: "This is the treaty of peace between the apostle of God." . . . Sohail anew protested; to acknowledge Mohammed as the apostle of God, would be to declare himself his follower; the designation ought to be simply Mohammed b. 'Abdalláh. The Moslems murmured louder than before, and refused to consent to the change. The heads of the two tribes of Medina, Osaid b. Ḥoḍair and Sa'd b. 'Obáda, held the hand of the scribe and declared that "Mohammed the apostle of God" must be written, or the sword must decide. The Meccan representatives whispered to one another words of amazement at the spirit displayed by these men. But Mohammed made a sign to the zealots to hold their peace, and again gave way (sur. xvii. 110). The writing which now took shape ran as follows:—

"In thy name, O God! This is the treaty of peace concluded by Mohammed b. 'Abdalláh and Sohail b. 'Amr. They have agreed to allow their arms to rest for ten years. During this time each party shall be secure, and neither shall injure the other; no secret damage shall be inflicted, but uprightness and honour prevail betwixt us. Whosoever wishes to enter into treaty and covenant with Mohammed can do so, and whosoever wishes to enter into treaty and covenant with the Koraish can do so. But if a Koraishite comes without permission of his guardian (Walí) to Mohammed, he shall be delivered up; but if, on the other hand, one of Mohammed's people comes to the Koraish he shall not be delivered up. This year Mohammed with his companions must withdraw from us,[3] but next year he may come amongst us and remain for three days, yet without other weapons than those of a traveller, the swords remaining in their sheaths." The treaty.

The first result of the treaty was that the Khozá'a declared for alliance with Mohammed; while, on the other hand, the Bekr b. Kinána joined themselves to the Ḳoraish.

To compensate his followers for the apparent resultlessness of this expedition, Mohammed immediately after their return led them out against the rich Jews of Khaibar (northwards from Medina), whither the Banú Naḍír had migrated, and from which place they had unceasingly stirred up opposition against the Prophet. Hitherto he had contented himself with putting out of the way, by means of assassination, some of their leading men who seemed to him to be particularly dangerous, such as Abú Ráfi' and Yosair b. Rázim,[4] but now he resorted to wholesale measures. In Moḥarram, A.H. 7 (May 628), he made his appearance before Khaibar with a powerful army; in the plunder only those who had taken part in the expedition of Ḥodaibiya were to share, but many others besides accompanied them. The Jews, although aware of the hostility of Mohammed's intentions, were nevertheless taken completely by surprise when one morning they saw him and his troops encamp before their strongholds. One of their leaders had given them the excellent advice not to shut themselves up by families in their quarters, but to construct a common camp in the fields, otherwise they were likely to share the fate of their coreligionists in Medina. But they replied that their strongholds were of a different sort, perched on impregnable summits, and they remained shut up within them. They had neither discipline nor order, courage nor devotion. As they were wanting in community of feeling, so also were they lacking in leaders. Their best man, Salám b. Mishkám, lay on a sick-bed; his place was by no means supplied by Kinána b. b. Abi 'l-Ḥoḳaiḳ. When they suddenly became aware that they had been completely abandoned by their Arab allies, the Ghaṭafán, their heart utterly failed them. When besieged in any of their citadels, they hardly ever waited War with Khaibar.

[1] Nöldeke, *Tabari*, p. 303, note 1; *Vakidi*, p. 18.

[2] Raḥmán is a name of God which Mohammed had taken from the Jews and used with special preference.

[3] The "us" is remarkable, and sounds as if the treaty had been dictated by the Meccans.

[4] *Vakidi*, pp. 170, 239.

were driven in chains to the house of Osáma b. Zaid, whence on the following morning Mohammed caused them to be brought one by one to the market-place of Medina, and there executed. This continued till late in the evening. They were six or seven hundred in number, and among them was the Nadirite Ḥoyay b. Akhṭab, the author of the War of the Fosse, who had left the Meccans to join his fortunes with those of the Ḳoraiẓa. By accepting Islám these men could have saved their lives, but they preferred death. No more magnificent martyrdom is known to history. The women and children were sold into slavery; one young woman only, Banána, suffered the penalty of death for having broken the head of a Moslem with a millstone during the siege. With joyous heart and smiling face she went to meet her death, never forgotten by 'Áisha, with whom she was when her name was called. The Prophet selected for himself the fair Raiḥána, and married her, after having caused her to become a convert to Islam.

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Hodaibiya. Mohammed was forced to halt at Ḥodaibiya on the borders of the sacred territory, and it was in vain that by fair speeches he sought to obtain permission to make the circuit of the Ka'ba. He felt himself too weak to force his way, and accordingly preferred to treat. While the envoys were passing to and fro, there suddenly arose an alarm in the Moslem camp; they apprehended a sudden act of treachery on the part of the Meccans. It was on this occasion that the famous Homage under the Tree took place, when Mohammed pledged his followers by striking hands that they would stand by him and go to death for his sake. Some of the Ḳoraish agents witnessed the scene, and were immensely impressed by it; such an enthusiastic obedience as Mohammed received, such an ascendency over the minds of men as he exercised, they had never before conceived to be possible, and on their return they urged their people in the strongest way not to permit matters to come to extremities. The Ḳoraish accordingly judged it best to offer a bargain with Mohammed, the terms being that for this year he was to withdraw, so that the Arabs might not say that he had forced an entrance, but that on the following year he was to return and be permitted to remain three days within the sacred territory for the purpose of sacrifice. After some discussion Mohammed accepted this proposal, although zealous Moslems detected a discreditable shortcoming in matters of faith, in so far as it involved turning back within sight of the Ka'ba without being allowed to accomplish the sacred circuit. When the agreement was to be committed to writing, Mohammed dictated the words: "In the name of Alláh, the merciful Raḥmán";[2] but the Meccan plenipotentiary, Sohail b. 'Amr, declared that he knew nothing about Raḥmán, and insisted upon the customary formula—"In thy name, Allá-homma!" The Moslems murmured, but Mohammed yielded. He then went on to dictate: "This is the treaty of peace between the apostle of God." . . . Sohail anew protested; to acknowledge Mohammed as the apostle of God, would be to declare himself his follower; the designation ought to be simply Mohammed b. 'Abdalláh. The Moslems murmured louder than before, and refused to consent to the change. The heads of the two tribes of Medina, Osaid b. Ḥodair and Sa'd b. 'Obáda, held the hand of the scribe and declared that "Mohammed the apostle of God" must be written, or the sword must decide. The Meccan representatives whispered to one another words of amazement at the spirit displayed by these men. But Mohammed made a sign to the zealots to hold their peace, and again gave way (sur. xvii. 110). The writing which now took shape ran as follows:—

> "In thy name, O God! This is the treaty of peace concluded by Mohammed b. 'Abdalláh and Sohail b. 'Amr. They have agreed to allow their arms to rest for ten years. During this time each party shall be secure, and neither shall injure the other; no secret damage shall be inflicted, but uprightness and honour prevail betwixt us. Whosoever wishes to enter into treaty and covenant with Mohammed can do so, and whosoever wishes to enter into treaty and covenant with the Ḳoraish can do so. But if a Ḳoraishite comes without permission of his guardian (Walí) to Mohammed, he shall be delivered up; but if, on the other hand, one of Mohammed's people comes to the Koraish he shall not be delivered up. This year Mohammed with his companions must withdraw from us,[3] but next year he may come amongst us and remain for three days, yet without other weapons than those of a traveller, the swords remaining in their sheaths." The treaty.

The first result of the treaty was that the Khozá'a declared for alliance with Mohammed; while, on the other hand, the Bekr b. Kinána joined themselves to the Ḳoraish.

War with Khaibar. To compensate his followers for the apparent resultlessness of this expedition, Mohammed immediately after their return led them out against the rich Jews of Khaibar (northwards from Medina), whither the Banú Naḍír had migrated, and from which place they had unceasingly stirred up opposition against the Prophet. Hitherto he had contented himself with putting out of the way, by means of assassination, some of their leading men who seemed to him to be particularly dangerous, such as Abú Ráfi' and Yosair b. Rázim,[4] but now he resorted to wholesale measures. In Moḥarram, A.H. 7 (May 628), he made his appearance before Khaibar with a powerful army; in the plunder only those who had taken part in the expedition of Ḥodaibiya were to share, but many others besides accompanied them. The Jews, although aware of the hostility of Mohammed's intentions, were nevertheless taken completely by surprise when one morning they saw him and his troops encamp before their strongholds. One of their leaders had given them the excellent advice not to shut themselves up by families in their quarters, but to construct a common camp in the fields, otherwise they were likely to share the fate of their coreligionists in Medina. But they replied that their strongholds were of a different sort, perched on impregnable summits, and they remained shut up within them. They had neither discipline nor order, courage nor devotion. As they were wanting in community of feeling, so also were they lacking in leaders. Their best man, Salám b. Mishkám, lay on a sick-bed; his place was by no means supplied by Kinána b. b. Abí 'l-Ḥoḳaiḳ. When they suddenly became aware that they had been completely abandoned by their Arab allies, the Ghaṭafán, their heart utterly failed them. When besieged in any of their citadels, they hardly ever waited

[1] Nöldeke, *Tabari*, p. 303, note 1; *Vakidi*, p. 18.
[2] Raḥmán is a name of God which Mohammed had taken from the Jews and used with special preference.
[3] The "us" is remarkable, and sounds as if the treaty had been dictated by the Meccans.
[4] *Vakidi*, pp. 170, 239.

ites complained to the Prophet, who eagerly seized the pretext for war. In vain did the Meccans send Abú Sofyán to Medina to renew the truce; they could not move the Prophet from his purpose. In Ramadan, A.H. 8 (January 630), he moved against Mecca with an army of 10,000 men. With the Emigrants and the Defenders were mustered the Aslam, Ghifár, Mozaina, Johaina, and Ashja'; the Solaim and the Khozá'a joined them on the way. The Bedouins were drawn by the hope of booty; the Fazárite 'Oyaina was sorely vexed that he had left his Ghaṭafán at home, not knowing what was in view, for Mohammed at first kept the aim of his expedition a secret. Some of the Meccan nobles must, however, have known it; Makhrama b. Naufal, for example, and the Prophet's uncle, 'Abbás, did not await the capture of their city, but deserted to the enemy while he was still distant. Abú Sofyán, in particular, must have been in the secret; it appears that at Medina he received the promise that the holy city should be spared if it yielded pacifically, and that he pledged himself to do his best to play into the hands of the Prophet.[1] But before the populace it was necessary to keep up the appearance of a sudden surprise, an inevitable submission to an unforeseen display of force. The same comedy was repeated afterwards at Ṭáif; the headmen treated with the Prophet without consulting the Thaḳafites, and then contrived that the result of their policy should appear to be forced by the course of events. The Moslems were on the border of the holy land before the Meccans suspected their approach; then suddenly one night 10,000 fires were seen rising to heaven to the north-west of the holy city. In well-feigned surprise Abú Sofyán hastened to the hostile camp; he returned with the news that the Moslems were at the gates, that an improvised resistance could effect nothing against their force; the only wise course was a surrender—Mohammed had promised security to those who remained in their houses or threw away their weapons. The terrified Meccans had hardly any other course open to them than to follow this advice. And now the Moslems entered the city from several sides at once, meeting only at one point with an easily quelled resistance. Mohammed insisted that there should be no violence; he pledged the captains to avoid all bloodshed. Ten persons only were put to the ban, and of these one half were subsequently pardoned. He took all pains to preserve the sanctity of Mecca unimpaired, confirmed the rights and privileges therewith connected, and made it plain that the old cultus should not be less flourishing under Islam. The ceremonies were retained, save only that he abolished all idols, both the domestic gods found in every house and the images in and round the Ka'ba. But every sanctuary outside of Mecca was destroyed, except such as had a part in the celebration of the Feast, and so stood in connexion with the Ka'ba itself. Thus the Meccan worship gained a new and unique importance. Mohammed's reform did for Mecca what Josiah's did for Jerusalem.[2]

The war is renewed.

Conquest of Mecca.

The last step towards that identification of the Ka'ba with Islam, which made it the religious centre of the Moslem world, was not taken till the following year, when the famous Renunciation (Bará'a) of sur. ix. forbade the heathen to share in the Feast, which was henceforth to be a strictly Moslem ordinance, and at the same time abrogated the peace of the holy months. A year later (Dhú 'l-Ḥijja, A.H. 10, March 632) he himself celebrated the Feast for the first time in the orthodox fashion, introducing certain modifications on the traditional practice and reducing certain varieties of use to uniform rule. In all this he professed to re-establish the true ancient use, purged of heretical deviations from the example of Abraham. At the same time he remodelled the Calendar, forbidding the occasional interpolation of a month as an arbitrary and human invention, and establishing the true lunar year of twelve lunations.

We return to the capture of Mecca. The submission of the Koraish was followed by that of their nomad brethren and allies. But the neighbouring Hawázin, to whom belonged also the Thaḳafite inhabitants of Ṭáif, assembled for battle with the Moslems. They camped in Autás between Ṭáif and Mecca. Mohammed advanced against them, and battle was joined in the valley of Honain. The Moslems were broken by the first charge of the foe; for a moment the Prophet himself was in danger, till the Khazraj rallied round him, checked the onset of the Hawázin, and at length turned them to flight. A vast booty rewarded the victors; for the Hawázin had brought all their herds and non-combatants with them and placed them in the rear, that they might feel what they were fighting for.[3] Mohammed caused the prey to be conveyed to the glen of Ji'rána, outside the north-west border of the Haram, a little way off the great valley that descends from Ṭáif; he himself pressed on to Ṭáif itself. Here, however, he failed in his object; in a dream he saw a cock peck a hole in a bowl of cream that was set before him, so that the contents ran out. After fourteen days he gave up the siege and marched to Ji'rána to deal with the booty. He had deferred this task in the hope that the Hawázin would be tempted to embrace Islam in order to recover their families and cattle. But as they still sent no ambassadors, he had to yield to the pressure of the Bedouins and divide the spoil. When it was too late, the messengers of the Hawázin appeared to announce their conversion; they had now to give up their herds, and content themselves that their wives and children were restored to them, through the mediation of the Prophet with their new masters. The Bedouins received compensation for what they gave up; the Emigrants and Defenders gave up their captives freely. Altogether the men of Medina fared worst in the distribution of booty, though they had borne the brunt of the conflict; those who fared best were the nobles of Mecca, who had no share in the fight, but whom Mohammed desired to conciliate by gifts (sur. ix. 60).

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The fall of Mecca reacted powerfully on the future development of Islam. Again the saying came true: *victa victores cepit;* the victory of the Moslems over the Koraish shaped itself into a domination of the Koraish over the Moslems. For this the Prophet himself was to blame. In making Mecca the Jerusalem of Islam, he was ostensibly moved by religious motives; but in reality Mohammed's religion had nothing to do with the heathenish usages at the Ka'ba and the Great Feast. To represent Abraham as the founder of the ritual was merely a pious fraud. What Mohammed actually sought, was to recommend Islam to Arabic prejudices by incorporating this fragment of heathenism, and at the same time he was influenced by his local patriotism. Henceforth these local feelings became quite the mainspring of his conduct; his attitude to the Koraish was determined entirely by the spirit of clannishness. Hence the extraordinary value he set on the conciliation of their chiefs; one gains the impression that he cared more for this than for the conversion of all the rest of the world. He left to them all that they already had; he gave them in addition whatever they asked, if only they would be his good friends. Abú Sofyán was a great man already, but Mohammed hastened

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and added that Mohammed's emissaries would presently appear to destroy the Rabba. The destruction took place accordingly, to the terror of the women and children, but without a *single man raising his hand.*

The pilgrimage undertaken by Mohammed in the year 10 (March 632) was like a very triumph. All Arabia, apart from the vassals of Persia and Greece, lay at his feet. The greatest success of his life had been effected by sheer moral force without a stroke of the sword. But Arabia no longer sufficed him; he had wider aims. In his last years he began to extend the holy war against the Greeks. Even on his return from Ḥodaibiya, he began to direct envoys to several foreign potentates, with letters demanding their adhesion to Islam. One of these envoys was seized and beheaded in the Belḳá (the ancient Moab). Hence sprang the first campaign against the Greeks, *i.e.* the Arabs who were subject to the Greek empire. The army directed against them was, however, entirely defeated at Mu'ta (Autumn 629); Khálid succeeded with difficulty in rallying and leading back the broken remnant of the host. Next summer the Nabatæans who visited the market of Medina spread a rumour that the Emperor Heraclius was collecting a vast force to attack the Moslems; and Mohammed set forth to meet him at the head of 30,000 men, but got no farther than Tabúk, on the southern borders of ancient Edom, when the rumour was found to be false. The expedition, however, was not altogether fruitless, as it led to the submission of several small Jewish and Christian communities in the north of the Peninsula. Mohammed equipped a new expedition against the Greeks on his return from his "farewell pilgrimage," and it was just ready to start when he died, on Monday, 8th June 632.

War with the Greeks.

Death of Mohammed.

In forming an estimate of one who has exercised so unexampled an influence on the history of the world, we shall do well to bear in mind the hint of Gibbon, that "some reverence is surely due to the fame of heroes and the religion of nations." The grounds on which Mohammed may be condemned are partly found in his private life. Although on the whole, even after he had become ruler of all Arabia, he maintained the original poverty and simplicity of his establishment, never set store by money and estate, eating and drinking and soft clothing, strictly continued to fast and watch and pray after his first fashion, and that, too, plainly out of a heartfelt need and without any ostentation, he nevertheless in one point at least used his supreme authority as prophet to make provision for the flesh. He claimed to be personally exempt from those restrictions in regard to the female sex which lay upon all other Moslems, and, as is well known, he made very extensive application of this fundamental principle. This fact is quite rightly urged against him as a reproach; even pious Moslems have been scandalised by it. At the same time, it is unnecessary to judge him on this account more harshly than we do Charlemagne, the most Christian king of the Franks; in any case we must not apply the standards of the present day to the circumstances of old Arabia. Of much weightier and indeed of crushing character is the accusation, that he did not really believe himself to be a prophet, but merely of set purpose played the part of one. For the first years of his activity indeed this charge is not now any longer maintained; it is universally granted that at that period his enthusiasm was genuine and real. But in Medina, we are told, he used his prophetic character simply as a pretext for the establishment of his power. It seems to the present writer that into this opinion there enter modern notions as to the separation between religion and the civil magistracy, which ought to be carefully kept out of sight. By any other instrumentality than that of a prophet it would hardly have been possible to found the state of Medina; religion was the soul of the community. The founding of a religion and the forming of a state were not connected in so merely external a way as is usually supposed; on the contrary, the one was the natural and necessary consequence of the other. This must certainly be conceded, that, if we are to make any distinctions at all, Islam was far less rich in religious meaning than in social forces. The Koran is Mohammed's weakest performance; the weight of his historical importance lies in his work at Medina and not in that at Mecca. And it is a fact that the politician in him outgrew the prophet more and more, and that in many cases where he assigned spiritual motives he merely did so to give a fair appearance to acts that emanated from secular regards. In this respect it appears to us particularly objectionable that he gave out as revelations of God and placed in the Koran all sorts of regulations and orders of the day, which proceeded simply from his own deliberations or even in part were suggested to him by advisers from outside. At the same time the element of self-deception is not excluded even here; he took for a message sent down from heaven everything which in his cataleptic fits passed through his mind, however close might be its agreement with his own previously cherished thoughts. It was pardonable that he went on with the idea after he had once grasped it, that he blew upon the coals when the flame threatened to die out. It is less easy to free him from the reproach of perfidy and cruel vindictiveness. The surprise of Nakhla in the month Rajab (ordered by him, though he afterwards repudiated it), the numerous assassinations which he instigated, the execution of the 600 Jews at the close of the War of the Fosse, burden the Prophet heavily, and sufficiently explain the widespread antipathy in which he is held. Yet even in this respect it is well not to forget the instance, already cited, of Charlemagne. It is precisely the man of vast aims who finds it most difficult to keep the beaten path.

After the death of Mohammed arose the question who was to be his "representative" (Khalífa, Caliph). The choice lay with the community of Medina; so much was understood; but whom were they to choose? The natives of Medina believed themselves to be now once more masters in their own house, and wished to promote one of themselves. But the Emigrants asserted their opposing claims, and with success, having brought into the town a considerable number of outside Moslems,[1] so as to terrorize the men of Medina, who besides were still divided into two parties. The Emigrants' leading spirit was 'Omar; he did not, however, cause homage to be paid to himself but to Abúbekr, the friend and father-in-law of the Prophet.

Abúbekr Caliph.

The affair would not have gone on so smoothly, had not the opportune defection of the Arabians put a stop to the inward schism which threatened. Islam suddenly found itself once more limited to the community of Medina; only Mecca and Ṭáif remained true. The Bedouins were willing enough to pray, indeed, but less willing to pay taxes; their defection, as might have been expected, was a political movement.[2] None the less was it a revolt from Islam, for here the political society and the religious are identical. A peculiar compliment to Mohammed was involved in the fact that the leaders of the rebellion in the various districts did not pose as princes and kings, but as prophets; in this the secret of Islam's success appeared to lie.

Revolt of the Arabs.

Abúbekr proved himself quite equal to the perilous situation. In the first place, he allowed the expedition against the Greeks, already arranged by Mohammed, quietly to set out, limiting himself for the time to the defence of Medina. On the return of the army he proceeded to

[1] Compare Muir, iv. 263.

[2] See Nöldeke, *Beiträge zur Kenntniss der Poesie der alten Araber* (1864), p. 89 *sq.*

and added that Mohammed's emissaries would presently appear to destroy the Rabba. The destruction took place accordingly, to the terror of the women and children, but without a single man raising his hand.

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War with the Greeks.

Death of Mohammed.

In forming an estimate of one who has exercised so unexampled an influence on the history of the world, we shall do well to bear in mind the hint of Gibbon, that "some reverence is surely due to the fame of heroes and the religion of nations." The grounds on which Mohammed may be condemned are partly found in his private life. Although on the whole, even after he had become ruler of all Arabia, he maintained the original poverty and simplicity of his establishment, never set store by money and estate, eating and drinking and soft clothing, strictly continued to fast and watch and pray after his first fashion, and that, too, plainly out of a heartfelt need and without any ostentation, he nevertheless in one point at least used his supreme authority as prophet to make provision for the flesh. He claimed to be personally exempt from those restrictions in regard to the female sex which lay upon all other Moslems, and, as is well known, he made very extensive application of this fundamental principle. This fact is quite rightly urged against him as a reproach; even pious Moslems have been scandalised by it. At the same time, it is unnecessary to judge him on this account more harshly than we do Charlemagne, the most Christian king of the Franks; in any case we must not apply the standards of the present day to the circumstances of old Arabia. Of much weightier and indeed of crushing character is the accusation, that he did not really believe himself to be a prophet, but merely of set purpose played the part of one. For the first years of his activity indeed this charge is not now any longer maintained; it is universally granted that at that period his enthusiasm was genuine and real. But in Medina, we are told, he used his prophetic character simply as a pretext for the establishment of his power. It seems to the present writer that into this opinion there enter modern notions as to the separation between religion and the civil magistracy, which ought to be carefully kept out of sight. By any other instrumentality than that of a prophet it would hardly have been possible to found the state of Medina; religion was the soul of the community. The founding of a religion and the forming of a state were not connected in so merely external a way as is usually supposed; on the contrary, the one was the natural and necessary consequence of the other. This must certainly be conceded, that, if we are to make any distinctions at all, Islam was far less rich in religious meaning than in social forces. The Koran is Mohammed's weakest performance; the weight of his historical importance lies in his work at Medina and not in that at Mecca. And it is a fact that the politician in him outgrew the prophet more and more, and that in many cases where he assigned spiritual motives he merely did so to give a fair appearance to acts that emanated from secular regards. In this respect it appears to us particularly objectionable that he gave out as revelations of God and placed in the Koran all sorts of regulations and orders of the day, which proceeded simply from his own deliberations or even in part were suggested to him by advisers from outside. At the same time the element of self-deception is not excluded even here; he took for a message sent down from heaven everything which in his cataleptic fits passed through his mind, however close might be its agreement with his own previously cherished thoughts. It was pardonable that he went on with the idea after he had once grasped it, that he blew upon the coals when the flame threatened to die out. It is less easy to free him from the reproach of perfidy and cruel vindictiveness. The surprise of Nakhla in the month Rajab (ordered by him, though he afterwards repudiated it), the numerous assassinations which he instigated, the execution of the 600 Jews at the close of the War of the Fosse, burden the Prophet heavily, and sufficiently explain the widespread antipathy in which he is held. Yet even in this respect it is well not to forget the instance, already cited, of Charlemagne. It is precisely the man of vast aims who finds it most difficult to keep the beaten path.

After the death of Mohammed arose the question who was to be his "representative" (Khalífa, Caliph). The choice lay with the community of Medina; so much was understood; but whom were they to choose? The natives of Medina believed themselves to be now once more masters in their own house, and wished to promote one of themselves. But the Emigrants asserted their opposing claims, and with success, having brought into the town a considerable number of outside Moslems,[1] so as to terrorize the men of Medina, who besides were still divided into two parties. The Emigrants' leading spirit was 'Omar; he did not, however, cause homage to be paid to himself but to Abúbekr, the friend and father-in-law of the Prophet.

Abúbekr Caliph.

The affair would not have gone on so smoothly, had not the opportune defection of the Arabians put a stop to the inward schism which threatened. Islam suddenly found itself once more limited to the community of Medina; only Mecca and Ṭáif remained true. The Bedouins were willing enough to pray, indeed, but less willing to pay taxes; their defection, as might have been expected, was a political movement.[2] None the less was it a revolt from Islam, for here the political society and the religious are identical. A peculiar compliment to Mohammed was involved in the fact that the leaders of the rebellion in the various districts did not pose as princes and kings, but as prophets; in this the secret of Islam's success appeared to lie.

Revolt of the Arabs.

Abúbekr proved himself quite equal to the perilous situation. In the first place, he allowed the expedition against the Greeks, already arranged by Mohammed, quietly to set out, limiting himself for the time to the defence of Medina. On the return of the army he proceeded to

[1] Compare Muir, iv. 263.

[2] See Nöldeke, *Beiträge zur Kenntniss der Poesie der alten Araber* (1864), p. 89 *sq.*

The fall of the Omayyads was their work, and with the Omayyads fell the Arabian empire. The course of Islam's political history during its first centuries is denoted by the removal of the capital from Damascus to Cufa, and from Cufa to Baghdád, the latter occupying, approximately, the site of the ancient Ctesiphon.

'Omar Caliph. But we must return to the period of Abúbekr. He died after a short reign, on 22d August 634, and as matter of course was succeeded by 'Omar. To 'Omar's ten years' Caliphate belong for the most part the great conquests. He himself did not take the field, but remained in Medina; he never, however, suffered the reins to slip from his grasp, so powerful was the influence of his personality and the Moslem community of feeling. His political insight is shown by the circumstance that he endeavoured to limit the indefinite extension of Moslem conquest, and to maintain and strengthen the national Arabian character of the commonwealth of Islam;[1] also by his making it his foremost task to promote law and order in its internal affairs. The saying with which he began his reign will never grow antiquated: "By God, he that is weakest among you shall be in my sight the strongest, until I have vindicated for him his rights; but him that is strongest will I treat as the weakest, until he complies with the laws." It would be impossible to give a better general definition of the function of the State. After the administration of justice he directed his organizing activity, as the circumstances demanded, chiefly towards financial questions—the incidence of taxation in the conquered territories,[2] and the application of the vast resources which poured into the treasury at Medina. It must not be brought against him as a personal reproach, that in dealing with these he acted on the principle that the Moslems were the chartered plunderers of all the rest of the world. But he had to atone by his death for the fault of his system; a workman at Cufa, driven to desperation by absurd fiscal oppressions, stabbed him in the mosque at Medina. He died in the beginning of November 644.

'Othmán Caliph. Before his death 'Omar had nominated six of the leading Emigrants who should choose the Caliph from among themselves—'Othmán, 'Alí, Zobair, Ṭalḥa, Sa'd b. Abí Waḳḳáṣ, and 'Abd al-Raḥmán b. 'Auf. The last named declined to be candidate, and decided the election in favour of 'Othmán b. 'Affán. Under this weak sovereign the government of Islam fell entirely into the hands of the Ḳoraish nobility. We have already seen that Mohammed himself prepared the way for this transference; Abúbekr and 'Omar likewise helped it; the Emigrants were unanimous among themselves in thinking that the precedence and leadership belonged to them as of right. Thanks to the energy of Omar, they were successful in appropriating to themselves the succession to the Prophet. They indeed rested the claims they put forward in the undeniable priority of their services to the faith, but they also appealed to their blood relationship with the Prophet, as a legitimation of their right to the inheritance; and the ties of blood connected them with the Ḳoraish in general. In point of fact they felt a greater solidarity with these than, for example, with the natives of Medina; nature had not been expelled by faith.[3] The supremacy of the Emigrants naturally furnished the means of transition to the supremacy of the Meccan aristocracy. 'Othmán did all in his power to press forward this development of affairs. He belonged to the foremost family of Mecca, the Omayyads, and that he should favour his relations and the Ḳoraish as a whole, in every possible way, seemed to him a matter of course. Every position of influence and emolument was assigned to them; they themselves boastingly called the important province of 'Iráḳ the garden of Ḳoraish. In truth, the entire empire had become that garden. Nor was it unreasonable that from the secularization of Islam the chief advantage should be reaped by those who best knew the world. Such were beyond all doubt the patricians of Mecca, and after them those of Ṭáif, people like Khálid b. al-Walid, 'Amr b. al-'Áṣ, 'Abdalláh b. Abí Sarh, Moghira b. Sho'ba, and, above all, old Abú Sofyán with his son Mo'áwiya, the governor of Syria.

Movement against 'Othmán. Against the rising tide of worldliness an opposition, however, now began to appear. It was led by what may be called the spiritual noblesse of Islam, which, as distinguished from the hereditary nobility of Mecca, might also be designated as the nobility of merit, consisting of the "Defenders," and especially of the Emigrants who had lent themselves to the elevation of the Ḳoraish, but by no means with the intention of allowing themselves to be thereby effaced. The opposition was headed by 'Alí, Zobair, Ṭalḥa, both as leading men among the Emigrants and as disappointed candidates for the Caliphate, who therefore were jealous of 'Othmán. Their motives were purely selfish; not God's cause but their own, not religion but power and preferment, were what they sought.[4] Their party was a mixed one. To it belonged the men of real piety, who saw with displeasure the promotion to the first places in the commonwealth of the great lords who had actually done nothing for Islam, and had joined themselves to it only at the twelfth hour, while those who had borne the burden and heat of the day were passed by. But the majority were merely a band of men without views, whose aim was not a change of system but of persons, that they themselves might fatten in the vacant places. Everywhere in the provinces there was agitation against the Caliph and his governors, except in Syria, where 'Othmán's cousin, Mo'áwiya b. Abí Sofyán, carried on a wise and strong administration. The movement was most energetic in 'Iráḳ and in Egypt. Its ultimate aim was the deposition of 'Othmán in favour of 'Alí, whose own services as well as his close relationship to the Prophet seemed to give him the best claim to the Caliphate. Even then there were enthusiasts who held him to be a sort of Messiah.

The malcontents sought to gain their end by force. In bands they came from the provinces to Medina to concuss 'Othmán into concession of their demands. From the Indus and Oxus to the Atlantic the world was trembling before the armies of the Caliph, but in Medina he had no troops at hand. He propitiated the mutineers by concessions, but as soon as they had gone, he let matters resume their old course. Thus things went on from worse to worse. In the following year (656) the leaders of the rebels came once more from Egypt and 'Iráḳ to Medina with a more numerous following; and the Caliph again tried his former plan of making promises which he did not intend to keep. But the rebels caught him in a flagrant breach of his word, and now demanded his abdication, besieging him in his own house, where he was

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[2] Nöldeke, *Tabari*, 246. To 'Omar also is due the establishment of the Era of the Flight.

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[4] It was the same opposition of the spiritual to the secular nobility that afterwards showed itself in the revolt of the sacred cities against the Omayyads. The movement triumphed with the elevation of the 'Abbásids to the throne. But, that the spiritual nobility was fighting not for principle but for personal advantage was as apparent in 'Alí's hostilities against Zobair and Ṭalḥa as in that of the 'Abbásids against the followers of 'Alí.

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The Caliph was not moved; threats prevailed over the obstinacy of the people of 'Irák, and Mo'áwiya repaired to Arabia in person, at the head of an army, to intimidate the inhabitants of Mecca and Medina. As may be supposed, the principal fomenters of the resistance in Arabia were the sons of the first Caliphs, 'Abd al-Rahmán the son of Abúbekr, 'Abdalláh the son of 'Omar, and Hosain the son of 'Alí; for, by submitting, they would have renounced all hope of being themselves chosen by the people. Another 'Abdalláh, son of that Zobair who had been among the six candidates nominated at the death of 'Omar for the choice of the Moslems, was also one of the warmest opponents of the pretensions of Mo'áwiya. All the efforts of the Caliph to win over these personages to his side having proved vain, he ordered them to be brought into the mosque at Mecca, each between two soldiers; then, having mounted the pulpit, he called on the bystanders to take the oath of allegiance to his son; adding that 'Abd al-Rahmán, Hosain, and the two 'Abdalláhs would raise no objection. They, in their terror, did not utter a word, and the assembly took the oath. Then Mo'áwiya, without concerning himself further about the malcontents, returned to Damascus.

While thus occupied at home, Mo'áwiya did not neglect foreign affairs. 'Amr b. al-'Ás, governor of Egypt, died A.H. 43 (A.D. 663-664), and was followed by several prefects in succession, under one of whom the general Mo'áwiya b. Hodaij undertook several expeditions into the province of Africa. In the year 50 (A.D. 670) he advanced as far as Camunia, now Súsa, near which city he laid the foundations of the celebrated Kairawán, and even went on to Sabaratha, a town situated near the seashore, and opposite to the island of C'rina. The emperor, Constantine IV., had sent thither thirty thousand Greeks, who were beaten and compelled to re-embark in haste. Mo'áwiya b. Hodaij returned to Egypt after his victory, and the Caliph now considered the position of the Moslems in Africa so strong, that he separated that province from Egypt, and appointed as governor of Africa 'Okba b. Náfi', who permanently established Kairawán, in a plain situated at a little distance from the first encampment of Mo'áwiya b. Hodaij. According to some historians, the new city was completed A.H. 55 (A.D. 674-675).

In the East the successes of the Moslems were still more brilliant. Ziyád, brother of Mo'áwiya, as soon as he was appointed governor of 'Irák and Persia, sent an army into Khorásán. It advanced as far as the Oxus, crossed that river, and returned loaded with booty taken from the wandering Turkish tribes of Transoxiana. Bokhárá was occupied by a son of Ziyád, and Sa'd, son of the Caliph 'Othmán, whom Mo'áwiya had made governor of Khorásán, marched against Samarkand, A.H. 56 (A.D. 675-676). Other generals penetrated as far as the Indus, and overran and conquered Múltán, Kábúlistán, Mokrán, and Sijistán.

In the North the Moslems were not less fortunate in their attacks on the Byzantine empire. Mo'áwiya, while still only governor of Syria, had gained possession of Armenia, and had sent a fleet against Cyprus, which, in conjunction with that of the governor of Egypt, had effected the conquest of that island. Encouraged by the result of this expedition, he gave the order for new incursions in the Mediterranean. His fleet of twelve hundred vessels invested the islands of Cos, Crete, and Rhodes. The famous Colossus of Rhodes was broken to pieces, and it is said that the bronze of which it was made was bought by a Jew of Emesa, and formed a load for nine hundred and eighty camels. The Arabs even dared to threaten Constantinople, which owed its safety only to the Greek fire. Yazíd, the son of Mo'áwiya, took part in these expeditions, but with no great ardour, and in the year 58 (A.D. 677-678) Mo'áwiya concluded a thirty years' peace with Constantine IV. Two years later, he died at Damascus, after a reign of nearly twenty years. He had been governor of Syria for the same length of time. Before his death, he sent for his son Yazíd, and having pointed out how he had smoothed down all difficulties for him, he advised him to spare no effort to preserve the attachment of the Syrians. He urged him also to keep a close watch on the actions of Hosain b. 'Alí, and of the other pretenders who had refused to take the oath of allegiance to him; but he added that, should they rebel, Yazíd ought to treat them with clemency, and not to forget their illustrious origin. By failing to act upon this wise advice, Yazíd rendered irreconcilable that formidable schism which, even at the present day, still divides the Moslem world, and which, at all periods, has been a source of calamity to Islam.

2. Yazíd had not his father's genius. Passionately fond of pleasure, and careless about religion, he bestowed more care on turning a pretty couplet than on consolidating the strength of his empire. During his short reign he committed three actions for which Moslems never pardoned his memory: the murder of Hosain, son of 'Alí and grandson of the Prophet; the pillage of Medina; and the taking of the Ka'ba, the venerated temple of Mecca; crimes which were not redeemed in the eyes of the people by a few fortunate expeditions on the part of his generals.[1] Yazíd I.

Immediately on ascending the throne, in the month Rajab A.H. 60 (April, A.D. 680), Yazíd sent a circular to all his prefects, with an official announcement of his father's death, and an order to administer the oath of allegiance to their respective subjects. In particular, he charged the new prefect whom he appointed to Medina, his own cousin Walíd b. 'Otba, to strike off the heads of Hosain son of 'Alí, 'Abd al-Rahmán son of Abúbekr, 'Abdalláh son of 'Omar, and 'Abdalláh son of Zobair, if they again refused to acknowledge him. Terrified at such a commission, Walíd did not dare to act with rigour against Hosain and 'Abdalláh b. Zobair, both of whom refused to take the oath, but allowed them to escape to Mecca. Yazíd immediately deprived him of his office, and appointed in his place 'Amr b. Sa'íd, already governor of Mecca. Once in the Holy City, 'Abdalláh b. Zobair thought himself in such perfect safety that he began to intrigue with the Meccans to have himself proclaimed Caliph in Arabia. At Cufa the news of the flight of Hosain produced great agitation among the partisans of the family of 'Alí, who were numerous there, and they sent several addresses to the grandson of the Prophet, inviting him to take refuge with them, and promising to have him proclaimed Caliph in 'Irák. Hosain, who knew the fickleness of the people of 'Irák, hesitated to yield to their entreaties; but Ibn Zobair, who was desirous to get rid at all costs of so formidable a rival, persuaded him that he ought to go and put himself at the head of the people of 'Irák, and enter on an open struggle with Yazíd. Hosain began by sending his cousin Moslim b. 'Akíl to Cufa, and from him he learned that many of the inhabitants of that city appeared really decided to support him. The prefect of Cufa, No'mán b. Bashír, though apprised of these proceedings, did not choose to make them known to Yazíd, as he was reluctant to act with severity against a descendant of the Prophet. Information, however, reached the Caliph, who deprived No'mán of his office, and ordered

[1] Salam b. Ziyád invaded Sogdiana, and brought back immense booty to Merv. In Africa 'Okba b. Náfi' invaded the whole coast of the Mediterranean as far as Morocco. On his return, however, he fell into an ambuscade laid by the Berbers, who killed him and took Kairawán.

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In the North the Moslems were not less fortunate in their attacks on the Byzantine empire. Mo'áwiya, while still only governor of Syria, had gained possession of Armenia, and had sent a fleet against Cyprus, which, in conjunction with that of the governor of Egypt, had effected the conquest of that island. Encouraged by the result of this expedition, he gave the order for new incursions in the Mediterranean. His fleet of twelve hundred vessels invested the islands of Cos, Crete, and Rhodes. The famous Colossus of Rhodes was broken to pieces, and it is said that the bronze of which it was made was bought by a Jew of Emesa, and formed a load for nine hundred and eighty camels. The Arabs even dared to threaten Constantinople, which owed its safety only to the Greek fire. Yazíd, the son of Mo'áwiya, took part in these expeditions, but with no great ardour, and in the year 58 (A.D. 677-678) Mo'áwiya concluded a thirty years' peace with Constantine IV. Two years later, he died at Damascus, after a reign of nearly twenty years. He had been governor of Syria for the same length of time. Before his death, he sent for his son Yazíd, and having pointed out how he had smoothed down all difficulties for him, he advised him to spare no effort to preserve the attachment of the Syrians. He urged him also to keep a close watch on the actions of Hosain b. 'Alí, and of the other pretenders who had refused to take the oath of allegiance to him; but he added that, should they rebel, Yazíd ought to treat them with clemency, and not to forget their illustrious origin. By failing to act upon this wise advice, Yazíd rendered irreconcilable that formidable schism which, even at the present day, still divides the Moslem world, and which, at all periods, has been a source of calamity to Islam.

2. Yazíd had not his father's genius. Passionately fond of pleasure, and careless about religion, he bestowed more care on turning a pretty couplet than on consolidating the strength of his empire. During his short reign he committed three actions for which Moslems never pardoned his memory: the murder of Hosain, son of 'Alí and grandson of the Prophet; the pillage of Medina; and the taking of the Ka'ba, the venerated temple of Mecca; crimes which were not redeemed in the eyes of the people by a few fortunate expeditions on the part of his generals.[1] Yazíd I.

Immediately on ascending the throne, in the month Rajab A.H. 60 (April, A.D. 680), Yazíd sent a circular to all his prefects, with an official announcement of his father's death, and an order to administer the oath of allegiance to their respective subjects. In particular, he charged the new prefect whom he appointed to Medina, his own cousin Walíd b. 'Otba, to strike off the heads of Hosain son of 'Alí, 'Abd al-Rahmán son of Abúbekr, 'Abdalláh son of 'Omar, and 'Abdalláh son of Zobair, if they again refused to acknowledge him. Terrified at such a commission, Walíd did not dare to act with rigour against Hosain and 'Abdalláh b. Zobair, both of whom refused to take the oath, but allowed them to escape to Mecca. Yazíd immediately deprived him of his office, and appointed in his place 'Amr b. Sa'íd, already governor of Mecca. Once in the Holy City, 'Abdalláh b. Zobair thought himself in such perfect safety that he began to intrigue with the Meccans to have himself proclaimed Caliph in Arabia. At Cufa the news of the flight of Hosain produced great agitation among the partisans of the family of 'Alí, who were numerous there, and they sent several addresses to the grandson of the Prophet, inviting him to take refuge with them, and promising to have him proclaimed Caliph in 'Irák. Hosain, who knew the fickleness of the people of 'Irák, hesitated to yield to their entreaties; but Ibn Zobair, who was desirous to get rid at all costs of so formidable a rival, persuaded him that he ought to go and put himself at the head of the people of 'Irák, and enter on an open struggle with Yazíd. Hosain began by sending his cousin Moslim b. 'Akíl to Cufa, and from him he learned that many of the inhabitants of that city appeared really decided to support him. The prefect of Cufa, No'mán b. Bashír, though apprised of these proceedings, did not choose to make them known to Yazíd, as he was reluctant to act with severity against a descendant of the Prophet. Information, however, reached the Caliph, who deprived No'mán of his office, and ordered

[1] Salam b. Ziyád invaded Sogdiana, and brought back immense booty to Merv. In Africa 'Okba b. Náfi' invaded the whole coast of the Mediterranean as far as Morocco. On his return, however, he fell into an ambuscade laid by the Berbers, who killed him and took Kairawán.

Ḥosain b. Nomair immediately offered the Caliphate to Ibn Zobair, on condition that he should grant a complete amnesty to all those who had taken part in the battle of Ḥarra and in the siege of Mecca. 'Abdalláh had the folly to refuse, and Ḥosain then returned to Damascus.

Ibn Zobair proclaimed Prince of the Believers.

Thus rid of his enemy, 'Abdalláh caused the title of Prince of the True Believers (*Amír al-mo'minín*) to be conferred on him—a title which 'Omar had already received, and which was afterwards adopted by all the Caliphs. He sent one of his brothers, 'Obaid Alláh, to Medina, and chose as governor of Egypt 'Abd al-Raḥmán b. Jaḥdam, who repaired to that province, and caused the authority of Ibn Zobair to be acknowledged there. At Baṣra and at Cufa, many of the inhabitants did not hesitate to acknowledge him, and received a Zobairite governor, while the Khárijites and the Shí'ites rose in revolt—the former at Baṣra under the leadership of Náfi' b. Azraḳ, the latter at Cufa under that of Solaimán b. Ṣorad—and expelled the Omayyad governor, 'Obaid Alláh b. Ziyád, who took refuge at Damascus. Mesopotamia soon followed the example of 'Iráḳ. Even in Syria, the population seemed disposed to forsake the cause of the Omayyads. The Khárijites and Mokhtár b. Abí 'Obaid, who had supported Ibn Zobair, now repented of having laboured for the elevation of this pretender, and quitted Mecca. The son of Zobair, remaining thenceforth sole master of Mecca, occupied himself tranquilly in rebuilding the Ka'ba, which he restored on its ancient foundations.

Mo'áwiya II.

3. It was in the midst of this break-up of his party that, immediately after the death of Yazíd, his eldest son, Mo'áwiya II., was elected Caliph at Damascus at the age of only seventeen or twenty. He was a young man of weak character, and imbued, it is said, with Shí'ite opinions. He felt himself incapable of ruling, and was contemplating abdication, when he died, after a reign of but forty days, by poison, as some say; of the plague, as others assert. The Caliphate was immediately offered to 'Othmán b. 'Otba b. Abí Sofyán, cousin of Mo'áwiya II.; for Khálid, the second son of Yazíd, was only sixteen years old. 'Othmán b. 'Otba, however, having made it a condition of his election that he should not be compelled to enter on any war, or to condemn any one to death, the choice fell at Damascus on Merwán b. al-Ḥakam, a descendant of Omayya through his grandfather Abú 'l-'Áṣ, but on condition that he should marry Maisún, the widow of Yazíd, and should appoint Khálid, her son, as his successor.

Merwán I.

4. Merwán b. al-Ḥakam had been secretary to the Caliph 'Othmán, and governor of Medina under Mo'áwiya I. Yazíd, on his accession to power, had dismissed him and put Walíd b. 'Otba in his place; but Merwán had continued to live at Medina, and had been driven from it during the revolt of the year 63, and again in the following year, when 'Obaid Alláh b. Zobair had taken possession of that city in the name of his brother. It might have been thought that Merwán would cherish a deep hatred of 'Abdalláh Ibn Zobair; but he was an old man of sixty-two at the time of his election, and, dreading an unequal struggle, he was on the point of making his submission to the Meccan Caliph. The drooping courage of Merwán was revived by his son 'Abd al-Melik and by 'Obaid Alláh b. Ziyád, and he resolved to try the chances of war.

Ḍaḥḥák b. Ḳais, governor of Damascus, had declared himself on the side of Ibn Zobair, and had raised an army, principally from among the tribe of Ḳais. This tribe had taken offence because Mo'áwiya I. and Yazíd had chosen their wives from the Yemenite tribe of Kalb, and, continuing to resent their conduct, now refused to acknowledge Khálid as the heir-presumptive of Merwán. It was therefore on the Yemenites that Merwán had to depend for the suppression of Ḍaḥḥák's rebellion. The latter had an army of nearly sixty thousand horsemen, while Merwán could bring together only thirteen thousand infantry. The two armies met at Marj Ráhiṭ, a few miles from Damascus, and, after a series of combats which lasted for twenty days, Merwán's troops gained a complete victory, and Ḍaḥḥák was among the killed. The Syrian provinces hastened to acknowledge the conqueror, and Merwán was able to turn his attention to Egypt, which, as will be remembered, had submitted to the Meccan. 'Abd al-'Azíz, a son of Merwán, had already marched to Aila on the Red Sea, and was preparing to enter Egypt; Merwán joined him, and the Zobairite governor of Egypt, beaten by their united forces, was obliged to seek safety in flight. Merwán made 'Abd al-'Azíz governor of the province. At the beginning of the year 65 (A.D. 684-685) Merwán returned in haste to Syria; for, during his absence, a brother of Ibn Zobair, named Moṣ'ab, had invaded that province. Merwán triumphed over Moṣ'ab; but an army of four thousand men, which he had sent to the Ḥijáz, and in which was Ḥajjáj b. Yúsuf—then quite a young man, but who afterwards played so important a part under 'Abd al-Melik—was cut to pieces. This defeat was redeemed by a victory gained by his generals, 'Obaid Alláh b. Ziyád and Ḥosain b. Nomair, at 'Ain al-Warda over a small army of Shí'ites led by Solaimán b. Ṣorad. But while the battle was being fought in Ramadan 65 (April-May 685), Merwán died; suffocated, it is said, by his wife Maisún, because he had insulted her son Khálid, and had broken his word by nominating his own son 'Abd al-Melik as his successor. The accession of 'Abd al-Melik was attended with no difficulty, as he was acknowledged by the whole of Syria and Egypt. The Ḳaisites naturally rallied round him, because he had not a drop of Yemenite blood in his veins.

'Abd al-Melik.

5. When 'Abd al-Melik ascended the throne, there still remained much to be done before the unity of the empire could be re-established. Ibn Zobair was still master of Arabia and of 'Iráḳ, though in the latter province his authority was very much shaken by the permanent rebellion of the Shí'ites at Cufa, and of the Khárijites at Baṣra. The Zobairite general Mohallab had, it is true, succeeded in forcing back the Khárijites into Susiana and Persia; but at Cufa the Shí'ites, at the instigation of Mokhtár, continued their agitation. Mokhtár, as we have seen, had withdrawn from Mecca after the raising of the siege by Ḥosain b. Nomair. He returned to Cufa, and there fomented serious disturbances. Many of the inhabitants of that city repented bitterly of having allowed Ḥosain, the grandson of the Prophet, to be massacred. Amid the general disorder of the Moslem empire, Mokhtár hoped to make his own authority acknowledged in 'Iráḳ and Mesopotamia. He put himself forward as the avenger of the family of 'Alí, and pretended to have been commissioned by a son of 'Alí, Mohammed b. Ḥanafíya,[1] who was living at Medina, to give effect to his rights to the Caliphate. Many Shí'ites believed him, and, detesting their chief Solaimán b. Ṣorad, joined Mokhtár. On learning these intrigues, the Zobairite governor threw him into prison. Soon after the defeat of Solaimán at 'Ain al-Warda, at the request of Mokhtár's brother-in-law, who was no other than 'Abdalláh the son of 'Omar, the governor consented to set him at liberty, on his swearing to make no further attempts against him. As Solaimán had fallen on the

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Hosain b. Nomair immediately offered the Caliphate to Ibn Zobair, on condition that he should grant a complete amnesty to all those who had taken part in the battle of Harra and in the siege of Mecca. 'Abdalláh had the folly to refuse, and Hosain then returned to Damascus.

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Dahhák b. Kais, governor of Damascus, had declared himself on the side of Ibn Zobair, and had raised an army, principally from among the tribe of Kais. This tribe had taken offence because Mo'áwiya I. and Yazíd had chosen their wives from the Yemenite tribe of Kalb, and, continuing to resent their conduct, now refused to acknowledge Khálid as the heir-presumptive of Merwán. It was therefore on the Yemenites that Merwán had to depend for the suppression of Dahhák's rebellion. The latter had an army of nearly sixty thousand horsemen, while Merwán could bring together only thirteen thousand infantry. The two armies met at Marj Ráhit, a few miles from Damascus, and, after a series of combats which lasted for twenty days, Merwán's troops gained a complete victory, and Dahhák was among the killed. The Syrian provinces hastened to acknowledge the conqueror, and Merwán was able to turn his attention to Egypt, which, as will be remembered, had submitted to the Meccan. 'Abd al-'Azíz, a son of Merwán, had already marched to Aila on the Red Sea, and was preparing to enter Egypt; Merwán joined him, and the Zobairite governor of Egypt, beaten by their united forces, was obliged to seek safety in flight. Merwán made 'Abd al-'Azíz governor of the province. At the beginning of the year 65 (A.D. 684-685) Merwán returned in haste to Syria; for, during his absence, a brother of Ibn Zobair, named Mos'ab, had invaded that province. Merwán triumphed over Mos'ab; but an army of four thousand men, which he had sent to the Hijáz, and in which was Hajjáj b. Yúsuf—then quite a young man, but who afterwards played so important a part under 'Abd al-Melik — was cut to pieces. This defeat was redeemed by a victory gained by his generals, 'Obaid Alláh b. Ziyád and Hosain b. Nomair, at 'Ain al-Warda over a small army of Shí'ites led by Solaimán b. Sorad. But while the battle was being fought in Ramadan 65 (April-May 685), Merwán died; suffocated, it is said, by his wife Maisún, because he had insulted her son Khálid, and had broken his word by nominating his own son 'Abd al-Melik as his successor. The accession of 'Abd al-Melik was attended with no difficulty, as he was acknowledged by the whole of Syria and Egypt. The Kaisites naturally rallied round him, because he had not a drop of Yemenite blood in his veins.

'Abd al-Melik. 5. When 'Abd al-Melik ascended the throne, there still remained much to be done before the unity of the empire could be re-established. Ibn Zobair was still master of Arabia and of 'Irák, though in the latter province his authority was very much shaken by the permanent rebellion of the Shí'ites at Cufa, and of the Khárijites at Basra. The Zobairite general Mohallab had, it is true, succeeded in forcing back the Khárijites into Susiana and Persia; but at Cufa the Shí'ites, at the instigation of Mokhtár, continued their agitation. Mokhtár, as we have seen, had withdrawn from Mecca after the raising of the siege by Hosain b. Nomair. He returned to Cufa, and there fomented serious disturbances. Many of the inhabitants of that city repented bitterly of having allowed Hosain, the grandson of the Prophet, to be massacred. Amid the general disorder of the Moslem empire, Mokhtár hoped to make his own authority acknowledged in 'Irák and Mesopotamia. He put himself forward as the avenger of the family of 'Alí, and pretended to have been commissioned by a son of 'Alí, Mohammed b. Hanafíya,[1] who was living at Medina, to give effect to his rights to the Caliphate. Many Shí'ites believed him, and, detesting their chief Solaimán b. Sorad, joined Mokhtár. On learning these intrigues, the Zobairite governor threw him into prison. Soon after the defeat of Solaimán at 'Ain al-Warda, at the request of Mokhtár's brother-in-law, who was no other than 'Abdalláh the son of 'Omar, the governor consented to set him at liberty, on his swearing to make no further attempts against him. As Solaimán had fallen on the

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for the time, for he required all his forces to dispute the empire with the son of Zobair. He consented, it is asserted, to pay the Greeks an indemnity of one thousand pieces of gold weekly. He then gave his attention to the renewal of the projected expedition against 'Irák. Moṣ'ab the Zobairite had rendered himself odious to the inhabitants of Baṣra and Cufa by his exactions, and a party favourable to 'Abd al-Melik was already forming in those cities. The Omayyad Caliph marched forth at the head of an army composed of Syrians and Egyptians, and encamped three parasangs from the plain of Dair al-Játhalík, not far from the site of Baghdád, where Moṣ'ab had established his army. Before joining battle, 'Abd al-Melik had written secretly to all the chiefs of Moṣ'ab's army, making them the most seductive promises if they would agree to desert the cause of Moṣ'ab. This step was crowned with success, and on the eve of the battle, which took place on the 13th Jomádí II., A.H. 71 (23d November 690), several of these generals passed into the camp of 'Abd al-Melik with arms and baggage. Moṣ'ab nevertheless attacked his enemy, but during the battle he found himself deserted by his troops, and, not choosing to survive his defeat, he caused himself to be slain. This victory opened the gates of Cufa to 'Abd al-Melik, and all 'Irák received him with acclamations. He remained forty days at Cufa, and then, having given the government to his brother Bishr, while Khálid b. 'Abdalláh received that of Baṣra, he returned in triumph to Damascus. Soon after, the Omayyad arms having sustained a check from the Khárijites in Fársistán, the Caliph gave Khálid orders to march against those sectaries with the support of Mohallab, who was their terror, and of the governor of Rey. Khálid succeeded completely in this expedition, and drove the Khárijites out of Ahwáz, Fársistán, and Kirmán. On his side, the Omayyad Caliph stirred up a revolt in Khorásán, a province which still remained faithful to the Zobairite cause. Its governor was treacherously assassinated by his lieutenant Bokair, who received, as the price of this service, the governorship of the province.

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Only Arabia now remained to Ibn Zobair. In A.H. 72 'Abd al-Melik made preparations for depriving him of it. Accordingly he raised an army; but when his generals found that another siege of Mecca was in contemplation, not one of them was willing to accept such a mission. An obscure officer, Ḥajjáj b. Yúsuf, boldly offered to lead the expedition. 'Abd al-Melik had little confidence in him, and therefore at first placed only two or three thousand horsemen under his command. Ḥajjáj set out, traversed the Ḥijáz without resistance, and pitched his camp at Ṭáif, not far from Mecca. Ibn Zobair tried to dislodge him; but in the frequent encounters between his troops and those of Ḥajjáj, the latter always had the advantage. 'Abd al-Melik then decided on sending him a reinforcement of five thousand men, on receiving which Ḥajjáj invested Mecca. The blockade lasted several months, during which the city was a prey to all the horrors of siege and famine. Ḥajjáj had set up balistas on the neighbouring heights, and poured a hail of stones on the city and the Ka'ba. Famine at length triumphed over the last adherents of the son of Zobair. Ten thousand fighting men, and even several of the sons of the pretender, left the city and surrendered. Mecca being thus left without defenders, Ḥajjáj took possession of it and invested the Ka'ba. Then the son of Zobair, seeing that ruin was inevitable, went to his mother Asmá, who had reached the age of a hundred, and asked her counsel. She answered that he must die sword in hand; and when, in embracing him for the last time, she felt the cuirass which he wore, she exclaimed that such a precaution was unworthy of a man resolved to perish. 'Abdalláh took off his cuirass, and taking refuge in the Ka'ba, passed the night there in prayer. At daybreak of the 14th of Jomádí I. in the year 73 (1st October 692), the Omayyad troops made their way into the mosque. 'Abdalláh attacked them furiously, notwithstanding his advanced age, but at last fell, overwhelmed by numbers. His head was cut off, carried to Ḥajjáj, and sent by the victorious general to Damascus.[1]

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Death of Ibn Zobair.

With Ibn Zobair perished the influence which the early companions of Mohammed had hitherto exercised over Islam. Medina and Mecca, though they continued to be the Holy Cities, had no longer the political importance which had enabled them to maintain a struggle with Damascus. Temporal interests, represented by Damascus, will henceforth have precedence over those of religion; policy will outweigh fanaticism;[2] and the centre of Islam, now permanently removed beyond the limits of Arabia, will be more easily affected by foreign influences, and assimilate more readily their civilizing elements. Damascus, Cufa, and Baṣra will attract the flower of all the Moslem provinces; and thus that great intellectual, literary, and scientific movement which is to reach its apogee under the 'Abbásid Caliphs at Baghdád, will become daily more marked.

By the death of the son of Zobair, 'Abd al-Melik remained sole Caliph; for Mohammed b. Ḥanafíya reckoned for nothing since the death of Mokhtár, whose creature he had been. The only remaining danger was from the Khárijites, who, though incessantly repulsed, as incessantly returned to the charge. Ḥajjáj had remained after his victory at Mecca, where he was occupied in rebuilding the Ka'ba, ruined for the second time by his engines of war. In the year 75, 'Abd al-Melik, alarmed at the news which reached him from Persia and 'Irák, named Ḥajjáj governor of that province, and gave him the most extensive powers for the re-establishment of order. The troops of 'Irák, who accompanied Mohallab in an expedition against the Khárijites, had abandoned their general and dispersed to their homes, and nothing could induce them to return to their duty. Ḥajjáj, arriving unexpectedly at Cufa, ascended the pulpit at the moment when the people were assembled for morning prayers, and delivered an energetic address to them, which depicts his character so well, that some passages from it may be cited:—

'Abd al-Melik sole Caliph.

Ḥajjáj in 'Irák.

"Men of Cufa, I see before me heads ripe for the harvest, and the reaper—I am he! I seem to myself already to see blood between turbans and shoulders. I am not one of those who can be frightened by an inflated bag of skin, nor need any one think to squeeze me like dried figs. I have been chosen on good grounds; and it is because I have been seen at work that I have been picked out from among others. The Prince of the Believers has spread before him the arrows of his quiver, and has tried every one of them by biting its wood. It is my wood that he has found the hardest and the bitterest, and I am the arrow which he shoots against you."

Thereupon Ḥajjáj ordered that every man capable of bearing arms should immediately join Mohallab in Susiana, and swore that all who made any delay should have their heads struck off. This threat produced its effect, and Ḥajjáj proceeded to Baṣra, where his presence was followed by the same result. Mohallab, reinforced by the army of 'Irák, at last succeeded, after a struggle of eighteen months, in subjugating the Khárijites, and was able, at the beginning of A.H. 78, to return to Ḥajjáj at Baṣra. The latter loaded him with honours and made him

[1] On these events, see Quatremère, *Mémoire historique sur la vie d'Abd-Allah b. Zobair.* Paris, 1832.

[2] It is said that the Caliph 'Abd al-Melik affected great piety before his elevation. At the moment when he was first saluted with the title of Caliph, he closed a copy of the Koran which was in his hands, saying: "We must now part."

for the time, for he required all his forces to dispute the empire with the son of Zobair. He consented, it is asserted, to pay the Greeks an indemnity of one thousand pieces of gold weekly. He then gave his attention to the renewal of the projected expedition against 'Irák. Moṣ'ab the Zobairite had rendered himself odious to the inhabitants of Baṣra and Cufa by his exactions, and a party favourable to 'Abd al-Melik was already forming in those cities. The Omayyad Caliph marched forth at the head of an army composed of Syrians and Egyptians, and encamped three parasangs from the plain of Dair al-Játhalík, not far from the site of Baghdád, where Moṣ'ab had established his army. Before joining battle, 'Abd al-Melik had written secretly to all the chiefs of Moṣ'ab's army, making them the most seductive promises if they would agree to desert the cause of Moṣ'ab. This step was crowned with success, and on the eve of the battle, which took place on the 13th Jomádí II., A.H. 71 (23d November 690), several of these generals passed into the camp of 'Abd al-Melik with arms and baggage. Moṣ'ab nevertheless attacked his enemy, but during the battle he found himself deserted by his troops, and, not choosing to survive his defeat, he caused himself to be slain. This victory opened the gates of Cufa to 'Abd al-Melik, and all 'Irák received him with acclamations. He remained forty days at Cufa, and then, having given the government to his brother Bishr, while Khálid b. 'Abdalláh received that of Baṣra, he returned in triumph to Damascus. Soon after, the Omayyad arms having sustained a check from the Khárijites in Fársistán, the Caliph gave Khálid orders to march against those sectaries with the support of Mohallab, who was their terror, and of the governor of Rey. Khálid succeeded completely in this expedition, and drove the Khárijites out of Ahwáz, Fársistán, and Kirmán. On his side, the Omayyad Caliph stirred up a revolt in Khorásán, a province which still remained faithful to the Zobairite cause. Its governor was treacherously assassinated by his lieutenant Bokair, who received, as the price of this service, the governorship of the province.

Defeat and death of Mos'ab.

Only Arabia now remained to Ibn Zobair. In A.H. 72 'Abd al-Melik made preparations for depriving him of it. Accordingly he raised an army; but when his generals found that another siege of Mecca was in contemplation, not one of them was willing to accept such a mission. An obscure officer, Ḥajjáj b. Yúsuf, boldly offered to lead the expedition. 'Abd al-Melik had little confidence in him, and therefore at first placed only two or three thousand horsemen under his command. Ḥajjáj set out, traversed the Ḥijáz without resistance, and pitched his camp at Ṭáif, not far from Mecca. Ibn Zobair tried to dislodge him; but in the frequent encounters between his troops and those of Ḥajjáj, the latter always had the advantage. 'Abd al-Melik then decided on sending him a reinforcement of five thousand men, on receiving which Ḥajjáj invested Mecca. The blockade lasted several months, during which the city was a prey to all the horrors of siege and famine. Ḥajjáj had set up balistas on the neighbouring heights, and poured a hail of stones on the city and the Ka'ba. Famine at length triumphed over the last adherents of the son of Zobair. Ten thousand fighting men, and even several of the sons of the pretender, left the city and surrendered. Mecca being thus left without defenders, Ḥajjáj took possession of it and invested the Ka'ba. Then the son of Zobair, seeing that ruin was inevitable, went to his mother Asmá, who had reached the age of a hundred, and asked her counsel. She answered that he must die sword in hand; and when, in embracing him for the last time, she felt the cuirass which he wore, she exclaimed that such a precaution was unworthy of a man resolved to perish. 'Abdalláh took off his cuirass, and taking refuge in the Ka'ba, passed the night there in prayer. At daybreak of the 14th of Jomádí I. in the year 73 (1st October 692), the Omayyad troops made their way into the mosque. 'Abdalláh attacked them furiously, notwithstanding his advanced age, but at last fell, overwhelmed by numbers. His head was cut off, carried to Ḥajjáj, and sent by the victorious general to Damascus.[1]

Second siege of Mecca.

Death of Ibn Zobair.

With Ibn Zobair perished the influence which the early companions of Mohammed had hitherto exercised over Islam. Medina and Mecca, though they continued to be the Holy Cities, had no longer the political importance which had enabled them to maintain a struggle with Damascus. Temporal interests, represented by Damascus, will henceforth have precedence over those of religion; policy will outweigh fanaticism;[2] and the centre of Islam, now permanently removed beyond the limits of Arabia, will be more easily affected by foreign influences, and assimilate more readily their civilizing elements. Damascus, Cufa, and Baṣra will attract the flower of all the Moslem provinces; and thus that great intellectual, literary, and scientific movement which is to reach its apogee under the 'Abbásid Caliphs at Baghdád, will become daily more marked.

By the death of the son of Zobair, 'Abd al-Melik remained sole Caliph; for Mohammed b. Ḥanafíya reckoned for nothing since the death of Mokhtár, whose creature he had been. The only remaining danger was from the Khárijites, who, though incessantly repulsed, as incessantly returned to the charge. Ḥajjáj had remained after his victory at Mecca, where he was occupied in rebuilding the Ka'ba, ruined for the second time by his engines of war. In the year 75, 'Abd al-Melik, alarmed at the news which reached him from Persia and 'Irák, named Ḥajjáj governor of that province, and gave him the most extensive powers for the re-establishment of order. The troops of 'Irák, who accompanied Mohallab in an expedition against the Khárijites, had abandoned their general and dispersed to their homes, and nothing could induce them to return to their duty. Ḥajjáj, arriving unexpectedly at Cufa, ascended the pulpit at the moment when the people were assembled for morning prayers, and delivered an energetic address to them, which depicts his character so well, that some passages from it may be cited:—

'Abd al-Melik sole Caliph.

Ḥajjáj in 'Irák.

> "Men of Cufa, I see before me heads ripe for the harvest, and the reaper—I am he! I seem to myself already to see blood between turbans and shoulders. I am not one of those who can be frightened by an inflated bag of skin, nor need any one think to squeeze me like dried figs. I have been chosen on good grounds; and it is because I have been seen at work that I have been picked out from among others. The Prince of the Believers has spread before him the arrows of his quiver, and has tried every one of them by biting its wood. It is my wood that he has found the hardest and the bitterest, and I am the arrow which he shoots against you."

Thereupon Ḥajjáj ordered that every man capable of bearing arms should immediately join Mohallab in Susiana, and swore that all who made any delay should have their heads struck off. This threat produced its effect, and Ḥajjáj proceeded to Baṣra, where his presence was followed by the same result. Mohallab, reinforced by the army of 'Irák, at last succeeded, after a struggle of eighteen months, in subjugating the Khárijites, and was able, at the beginning of A.H. 78, to return to Ḥajjáj at Baṣra. The latter loaded him with honours and made him

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Walíd I. 6. Immediately on his accession Walíd confirmed Ḥajjáj in the government of 'Iráḳ, and appointed as governor of Medina his cousin 'Omar b. 'Abd al-'Azíz, who was received there with joy, his piety and gentle character being well known. Under his government important works were undertaken at Medina and Mecca by order of Walíd, who, having no rivals to struggle against, was able to give his attention to pacific occupations. The mosque of Medina was enlarged, wells were sunk, the streets widened, and hospitals established. At Mecca many improvements were introduced. The reputation of 'Omar attracted to the two Holy Cities a great number of the inhabitants of 'Iráḳ, who were groaning under the iron hand of Ḥajjáj. The latter, who was not a man to let his prey escape from his grasp, was so urgent with Walíd that he obtained the dismissal of 'Omar b. 'Abd al-'Azíz in the year 93, and the appointment of 'Othmán b. Ḥayyán at Medina, and of Khálid b. 'Abdalláh at Mecca. These two prefects compelled the refugees at Mecca and Medina to return to 'Iráḳ, where many of them were cruelly treated and even put to death by Ḥajjáj. It was probably his cruelty which drove so many men of 'Iráḳ to enlist in the armies of the East and the South; and this may in some degree account for the unheard-of successes of Ḳotaiba b. Moslim in Transoxiana, and of Mohammed b. Ḳásim in India. They may also be explained by the ambition of Ḥajjáj, who, it is said, cherished the project of creating a vast empire for himself to the east and south of the Moslem realm, and had secretly promised the government of China to the first of his generals who should reach that country. Be this as it may, in the course of a very few years Ḳotaiba conquered the whole of Bokharia, Khárizm, and Transoxiana or Má wará-annahr, as far as the frontiers of China. Meanwhile Mohammed b. Ḳásim invaded Mokrán, Sind, and Múltán, carried off an immense booty, and reduced the women and children to slavery. In Armenia and Asia Minor, Maslama, brother of the Caliph Walíd, and his lieutenants, also obtained numerous successes against the Greeks. In Armenia, Maslama even advanced as far as the Caucasus.

Conquest of Spain. The most important achievement, however, of Walíd's reign was the conquest of Spain. The narrative of this conquest belongs specially to the history of Spain; and we shall therefore only touch briefly on it here. We have seen that, even in the Caliphate of 'Abd al-Melik, Músá b. Noṣair had penetrated as far as Tlemcen in Africa. Under Walíd, Músá, who had been appointed governor of Africa, entered Morocco, occupied Fez and Tangier, and then returned to Kairawán, having made his lieutenant Ṭáriḳ governor of Tangier and of all the West of Africa. The town of Ceuta still held out under its governor Julian, who held it in the name of Witiza, King of Spain. Witiza having been dethroned by Roderic, Julian thought he might find the Arabs useful allies in the struggle which he proposed to carry on against the usurper[3] and entered into negotiations with Ṭáriḳ. The latter, foreseeing the possibility of conquering for the advantage of the Arabs a country which had been represented to him as a paradise, requested instructions from Músá, who referred the matter to the Caliph. Walíd gave Músá *carte blanche*, and Ṭáriḳ hastened to make alliance with Julian. He first, however, sent four ships, with five hundred men under the command of Ṭaríf, to reconnoitre the country. This expedition was successful, and Ṭáriḳ, now certain of meeting no serious opposition to his landing, passed into Spain himself, at the head of twelve thousand men, in the year 92 (A.D. 710-711), and landed at the spot which thence received the name of Jabal-Ṭáriḳ, or "Mountain of Ṭáriḳ," a name which was afterwards corrupted by the Westerns into Gibraltar. At the news of this invasion, Roderic led a numerous army against the Arabs, but was completely routed near Cadiz, and perished in the conflict. Músá, jealous of the success of his lieutenant, hastened to Spain with eighteen thousand men, and his first step on arriving was to send Ṭáriḳ orders to suspend his march. But Ṭáriḳ, far from obeying, divided his little army into three corps, and obtained possession successively of Ecija, Malaga, Elvira, Cordova, and Toledo. Músá, hopeless of arresting the victorious march of Ṭáriḳ, determined to play the part of a conqueror himself, and took Seville, Carmona, and Merida. On rejoining Ṭáriḳ at Toledo, the first step he took was to throw him into prison. The Caliph, however, gave orders that he should be set at liberty and restored to his command. The two conquerors then shared the country between them, and, in less than three years, all Spain was subdued, to the very foot of the Pyrenees. Meanwhile Walíd, fearing to see Músá declare his independence, recalled him to Damascus. He obeyed after appointing his son 'Abd al-'Azíz governor of Spain, and assigning Seville as his residence. Músá left Spain in the month of Ṣafar, A.H. 95 (October-November 713), in company with Ṭáriḳ, bringing an immense booty to Damascus, and leading in his train a great number of prisoners. His journey from Ceuta to Damascus was one long triumph. He reached Egypt in the month of Rabí' I. in the following year (Nov.-Dec. 714), and then moved on by short marches towards Damascus, where he did not arrive till two months and a half later, at the very moment when Walíd had just breathed his last, and his brother Solaimán had been saluted as Caliph. The renowned Ḥajjáj had preceded his sovereign, and had expired five days before the end of Ramadan, A.H. 95. Músá did not receive the reward due to his distinguished services. Accused of peculation by the new Caliph, he was beaten with rods, and condemned to a fine of 100,000 pieces of gold; and all his goods were confiscated. Solaimán did not stop here: he caused 'Abd al-'Azíz, the son of Músá, to be put to death in Spain, and carried his cruelty so far as to show his severed head to Músá, asking him whether he recognised it. He replied that it was the head of a man a thousand times superior to him who had ordered his death. Músá died soon after. As for Ṭáriḳ, there is no further mention of him after the beginning of the reign of Solaimán, and we must therefore suppose that he retired into private life.

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ated in the south of Syria, on the confines of Arabia. It was in this retirement that his son Mohammed conceived the design of supplanting the Omayyad dynasty. We have said that the first 'Abbásids were closely united with the family of 'Alí. Mohammed b. 'Alí, the 'Abbásid, saw clearly that it was only among the followers of 'Alí that he was likely to be able to form a party. To attain this object, he formed the plan of making it believed that a descendant of the Prophet's son-in-law had transmitted to him his rights to the Caliphate. It will be remembered that Mohammed b. Ḥanafíya had come forward as a pretender to the throne at the troublous period when Ibn Zobair and 'Abd al-Melik were disputing the Caliphate. According to the story of the 'Abbásids, Abú Háshim 'Abdalláh, the son of Ibn Ḥanafíya, had gone to Ḥomaima, to the house of Mohammed b. 'Alí, and had made on his deathbed a legal transfer of his rights to Mohammed, by appointing him his heir. Whatever may be the truth respecting this transfer,[1] Mohammed the 'Abbásid spread abroad the report of it, and chose especially for its propagation the provinces in which the family of 'Alí had the greatest number of adherents, 'Irák and Khorásán. Emissaries sent by him into these two provinces, under the caliphate of 'Omar II., began to stir up the people in secret against the reigning house. 'Omar was probably acquainted with these intrigues, but he had not time to repress them, for he died on the 20th or 25th of Rajab, A.H. 101 (5th or 10th February 720), after a reign of about two years and a half.

Yazíd II. 9. Yazíd, the son of 'Abd al-Melik, ascended the throne without resistance. His first care was to pursue Yazíd b. Mohallab, who had escaped from his prison and taken refuge in 'Irák. Besides reasons of state, Yazíd II. had personal reasons for ill-will to Yazíd b. Mohallab. One of the wives of the new Caliph, the same who gave birth to that son of Yazíd II. who afterwards reigned under the name of Walíd II., was niece to the celebrated Ḥajjáj, who, as it will be remembered, had hated and persecuted Yazíd b. Mohallab. Aware of the alliance of the new Caliph with the family of Ḥajjáj, the son of Mohallab had made every effort to escape as soon as he was informed of the illness of 'Omar II.; for he well knew that Yazíd II. would spare neither him nor his family. In fact, the Caliph sent express orders to the prefect of 'Irák to arrest all the brothers and other members of the family of Mohallab who were to be found at Baṣra; and this order was immediately carried out. But Yazíd b. Mohallab had many partisans in 'Irák. He collected a small army, and fought with such valour that in a short time he succeeded in making himself master of Baṣra, where he had himself proclaimed Caliph. The public treasury fell into his hands, and he employed it in paying his troops and in raising fresh ones, whom he sent on expeditions into Khúzistán or Ahwáz, Fársistán, Mokrán, and Sind. As this revolt threatened to spread far and wide, Yazíd II. was obliged to have recourse for its suppression to the celebrated Maslama. Early in A.H. 102, this illustrious general took the field, and completely defeated Ibn Mohallab near Baṣra. Yazíd fell in the battle, and his brothers fled beyond the Indus, but were pursued and slain by the lieutenants of Maslama.

This revolt suppressed, Yazíd II. was able to give his thoughts to the extension of the empire, an object which had been so much neglected by his predecessor. Several expeditions were directed against Farghána in Transoxiana, against the Khazars in Armenia, and against the Greeks in Asia Minor, but without any very decided results. In Africa, serious troubles had been caused by the appointment as governor of a certain Yazíd b. Abí Moslim, who had been secretary to Ḥajjáj, and who followed the example of his master's implacable harshness. The Berbers rose in insurrection, slaughtered the unfortunate governor, and chose in his place Mohammed b. Aus. The Caliph at first ratified this choice, but soon after dismissed Mohammed from his post, and replaced him by Bishr b. Ṣafwán, who sent out an expedition against Sicily.

In Europe, the Arabs obtained at first some degree of success. Under the orders of Samaḥ, then governor of Spain, they crossed the Pyrenees, and took possession of Narbonne; but, having been beaten at Toulouse, they had to retrace their steps. It was the celebrated Abderame ('Abd al-Raḥmán) who effected their retreat.

Yazíd II. died three years later of a lingering illness, caused, it is said, by his grief for the death of a favourite slave-girl. At his accession, Yazíd had designated as his successors, in the first place his son Hishám, and in the second his son Walíd. Hishám ascended the throne without opposition.

10. Hishám was a pious prince and an enemy of luxury; as rigid in his religion as 'Omar II. To this severity may in part be attributed the disturbances which broke out in the provinces during his reign. The governors were accustomed to remain loyal to the Caliphs only when the latter did not exact from them too rigorous an account. Hishám was, besides, very avaricious, a fault highly calculated to make him odious to those about him. Lastly, he favoured the Yemenites, and this alienated from him the powerful party of the Ḳaisites. All these circumstances emboldened the 'Abbásids to carry on actively their propaganda in 'Irák and Khorásán, and it succeeded beyond their hopes. The Ḳaisite tribes, offended at seeing the Caliph bestow the best posts on Yemenites, were ready to espouse with enthusiasm the cause of any one whose aim was the overthrow of the Omayyads. Rebellion had been smouldering in the provinces for thirteen years; it broke out at last at Cufa and in the whole of 'Irák, under chiefs called Moghíra and Bahlúl; and when these insurgents had been chastised, others sprung up in their place, 'Amr al-Yashkorí, Al-'Anazí, and Al-Sakhtayání. The prefect of 'Irák, Khálid b. 'Abdalláh, was accused of favouring this revolt, was degraded, and replaced by Yúsuf b. 'Omar, who threw him into prison, where he remained for eighteen months. This measure increased the discontent of the people of 'Irák, and a member of the family of 'Alí, Zaid b. 'Alí, collected round him a small body of partisans, and had himself proclaimed Caliph, A.H. 122 (A.D. 739-740). Unfortunately for Zaid, he had to do with the same Cufans whose fickleness had already been fatal to his family. In the moment of danger he was deserted by his troops, slain in an unequal conflict, and his head sent to Damascus. In Khorásán also there were very serious disturbances. In the year 106 (A.D. 724-725) there had already been a revolt at Balkh, excited by the emissaries of the 'Abbásids. The following years brought with them fresh troubles, which led to the dismissal of the governor of Khorásán, Asad, the brother of Khálid b. 'Abdalláh, who had been prefect of 'Irák. Under the successors of Asad, who were successively Ashras b. 'Abdalláh, Jonaid b. 'Abd al-Raḥmán, and 'Áṣim b. 'Abdalláh, seditions broke out in Transoxiana, which were repressed with great difficulty; and it was not until the year 120 that, by the appointment of the brave and prudent Naṣr b. Sayyár as governor of Khorásán, peace was for a time restored to that region. The 'Abbásid emissaries, nevertheless, secretly continued their propaganda.

In India, several provinces which had been converted

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ated in the south of Syria, on the confines of Arabia. It was in this retirement that his son Mohammed conceived the design of supplanting the Omayyad dynasty. We have said that the first 'Abbásids were closely united with the family of 'Alí. Mohammed b. 'Alí, the 'Abbásid, saw clearly that it was only among the followers of 'Alí that he was likely to be able to form a party. To attain this object, he formed the plan of making it believed that a descendant of the Prophet's son-in-law had transmitted to him his rights to the Caliphate. It will be remembered that Mohammed b. Hanafíya had come forward as a pretender to the throne at the troublous period when Ibn Zobair and 'Abd al-Melik were disputing the Caliphate. According to the story of the 'Abbásids, Abú Háshim 'Abdalláh, the son of Ibn Hanafíya, had gone to Homaima, to the house of Mohammed b. 'Alí, and had made on his deathbed a legal transfer of his rights to Mohammed, by appointing him his heir. Whatever may be the truth respecting this transfer,[1] Mohammed the 'Abbásid spread abroad the report of it, and chose especially for its propagation the provinces in which the family of 'Alí had the greatest number of adherents, 'Irák and Khorásán. Emissaries sent by him into these two provinces, under the caliphate of 'Omar II., began to stir up the people in secret against the reigning house. 'Omar was probably acquainted with these intrigues, but he had not time to repress them, for he died on the 20th or 25th of Rajab, A.H. 101 (5th or 10th February 720), after a reign of about two years and a half.

Yazíd II. 9. Yazíd, the son of 'Abd al-Melik, ascended the throne without resistance. His first care was to pursue Yazíd b. Mohallab, who had escaped from his prison and taken refuge in 'Irák. Besides reasons of state, Yazíd II. had personal reasons for ill-will to Yazíd b. Mohallab. One of the wives of the new Caliph, the same who gave birth to that son of Yazíd II. who afterwards reigned under the name of Walíd II., was niece to the celebrated Hajjáj, who, as it will be remembered, had hated and persecuted Yazíd b. Mohallab. Aware of the alliance of the new Caliph with the family of Hajjáj, the son of Mohallab had made every effort to escape as soon as he was informed of the illness of 'Omar II.; for he well knew that Yazíd II. would spare neither him nor his family. In fact, the Caliph sent express orders to the prefect of 'Irák to arrest all the brothers and other members of the family of Mohallab who were to be found at Basra; and this order was immediately carried out. But Yazíd b. Mohallab had many partisans in 'Irák. He collected a small army, and fought with such valour that in a short time he succeeded in making himself master of Basra, where he had himself proclaimed Caliph. The public treasury fell into his hands, and he employed it in paying his troops and in raising fresh ones, whom he sent on expeditions into Khúzistán or Ahwáz, Fársistán, Mokrán, and Sind. As this revolt threatened to spread far and wide, Yazíd II. was obliged to have recourse for its suppression to the celebrated Maslama. Early in A.H. 102, this illustrious general took the field, and completely defeated Ibn Mohallab near Basra. Yazíd fell in the battle, and his brothers fled beyond the Indus, but were pursued and slain by the lieutenants of Maslama.

This revolt suppressed, Yazíd II. was able to give his thoughts to the extension of the empire, an object which had been so much neglected by his predecessor. Several expeditions were directed against Farghána in Transoxiana, against the Khazars in Armenia, and against the Greeks in Asia Minor, but without any very decided results. In Africa, serious troubles had been caused by the appointment as governor of a certain Yazíd b. Abí Moslim, who had been secretary to Hajjáj, and who followed the example of his master's implacable harshness. The Berbers rose in insurrection, slaughtered the unfortunate governor, and chose in his place Mohammed b. Aus. The Caliph at first ratified this choice, but soon after dismissed Mohammed from his post, and replaced him by Bishr b. Safwán, who sent out an expedition against Sicily.

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Mohammed had even foretold that the accession of his family would take place *in the year of the ass*,[1] through the efforts of Abú Moslim, and that one of his three sons would ascend the throne. These three sons were: Ibráhím, 'Abdalláh, called Abú 'l-'Abbás, and 'Abdalláh, called Abú Ja'far. Whatever we may think of this prediction, it is certain that under Merwán II. Abú Moslim was the principal emissary of the 'Abbásid Ibráhím, and had been able to form a vast conspiracy in Khorásán, which broke out in A.H. 128, at the very moment when it had been discovered by Naṣr b. Sayyár, the Omayyad governor of the province. Even before this, Merwán II. had had to repress disorders which had broken out in Syria, Palestine, and 'Irák; and the Caliph could now rely so little on Syria that he had thought it necessary to quit Damascus, and to fix his abode at Ḥarrán, in Mesopotamia. On learning the revolt of Abú Moslim, Merwán II. wrote to Naṣr b. Sayyár, directing him to act with vigour against the fomenters of sedition. It was easier to give such an order than to execute it, for Abú Moslim was at the head of a numerous army, absolutely devoted to the 'Abbásids. Merwán II. thought it necessary at the same time to secure the person of the 'Abbásid pretender Ibráhím, who was still living at Ḥomaima. Ibráhím was therefore arrested, conveyed to Ḥarrán, and thrown into prison. He found means, however, of communicating with his lieutenant Abú Moslim, and the latter, who had received the most extensive powers from his chief, marched direct upon Merv, the capital of Khorásán, and drove out the governor Naṣr. At the news of this the Caliph, no longer able to restrain his anger, had his captive Ibráhím put to death; an execution which, at a later period, brought upon the Omayyads the most terrible reprisals. The brother of Ibráhím, Abú 'l-'Abbás, surnamed Saffáḥ, "The Sanguinary," on account of his cruelties, having by Ibráhím's death become chief of the 'Abbásids, immediately quitted Ḥomaima with all the members of his family, and took refuge in Khorásán, that his presence there might sanction and encourage the insurrection. Abú Moslim, now master of Khorásán by the capture of Merv, had meanwhile sent an army against 'Irák, under the orders of Kaḥtaba b. Shabíb, who had beaten the Omayyad army, commanded by Yazíd b. Hobaira, governor of that province. In A.H. 132 Abú 'l-'Abbás arrived at Merv. After remaining there some time, waiting for a favourable moment, he decided on openly assuming the title of Caliph. He installed himself in the governor's palace, and thence went in state to the mosque, where he mounted the pulpit, and officiated in the capacity of successor of the Prophet. All those present took the oath of allegiance to him, and Abú 'l-'Abbás returned to the palace, over which the black flag was flying, black being the distinctive colour of the 'Abbásids.[2] But he did not remain long at Merv. Committing the government of that city to his uncle Dáwúd, he went to review his army, and divided it into several corps, which he directed against different points. After this he went to Chaldæa, and there established himself in a spot not far from Cufa, to which he gave the name of Háshimíya, or the city of Háshim, the ancestor of his own family and of that of the Prophet. Another of his uncles, 'Abdalláh b. 'Alí, whom he had sent on an expedition against the city of Shahrozúr, took possession of that place, and leaving Abú 'Aun 'Abd al-Melik b. Yazíd there as governor, rejoined his nephew and sovereign at Háshimíya. Meanwhile the Omayyad Caliph had marched against Shahrozúr. Abú 'Aun went out to meet him, and was joined by a strong reinforcement of cavalry under 'Abdalláh b. 'Alí. The 'Abbásids only numbered forty-five thousand soldiers, but these were experienced and resolute warriors. The Omayyad army, though much more numerous, was ill commanded and devoid of spirit. A battle ensued, and fortune favoured the rebels. In vain did Merwán show himself everywhere; his soldiers gave way and repassed the Záb in disorder, hurrying away in their flight the unfortunate Merwán. (Jomádí II. 11, A.H. 132, 25th January 750.) This victory cost the Omayyads their empire. Merwán attempted at first to take refuge at Mosul; but the inhabitants of that city having declared for the enemy, the prince went to his capital Ḥarrán, whence he was soon driven by the army of 'Abdalláh b. 'Alí. From Ḥarrán Merwán fled successively to Emesa, to Damascus, to Palestine, and finally to Egypt. He was pursued without intermission by Ṣáliḥ, brother of 'Abdalláh b. 'Alí, who at last came up with him at Búṣír, on the frontiers of the Delta. Merwán took refuge in a Coptic church; but the 'Abbásids pursued him into the building, and slew him at the foot of the altar. His head was cut off and sent to Cufa, where the new Caliph then was.

Al-Saffáh assumes the title of Caliph.

Triumph of the 'Abbásids.

Thus perished in the East the dynasty of the house of Omayya, which, having been founded by usurpation, had only maintained itself by shedding torrents of blood, and was destined to perish in blood. We now enter upon the history of the new dynasty, whose origin we have described, and under which the power and glory of Islam reached their highest point.

Here we give the

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dynasty, after having accomplished his work, which, as the historians assert, cost the lives of more than 600,000 men. Notwithstanding the defeat of 'Abdalláh b. 'Alí and the murder of Abú Moslim, the spirit of rebellion was not yet broken. Risings took place in Mesopotamia and to a still greater extent in Khorásán; and the Caliph's troops were repeatedly beaten by the rebels; but order was at last re-established by Manṣúr's generals, by Kházim b. Khozaima in Mesopotamia, and by Mohammed b. al-Ash'ath in Khorásán.

About the same time Africa and Spain escaped from the dominion of the Eastern Caliphate; the former for a season, the latter permanently. The cause of the revolt of Africa was as follows: As soon as Manṣúr ascended the throne, he wrote to 'Abd al-Raḥmán, announcing the death of Abú 'l-'Abbás, and requiring him to take the oath of allegiance. 'Abd al-Raḥmán sent in his adhesion to the new Caliph, and added a few presents of little value. The Caliph was so much dissatisfied that he replied by a threatening letter which excited the anger of 'Abd al-Raḥmán. He called the people together at the hour of prayer, mounted the pulpit, publicly cursed Manṣúr, and then declared his deposition from the Caliphate. He next caused a circular letter to be written, commanding all Maghrebins to refuse obedience to the Caliph; and this letter was circulated and read from the pulpit throughout the whole extent of the Maghrib (the West). A brother of 'Abd al-Raḥmán, Ilyás, saw in this revolt an opportunity of obtaining the government of Africa for himself. Seconded by many of the inhabitants of Ḳairawán, who had remained faithful to the cause of the 'Abbásids, he attacked his brother, slew him, and proclaimed himself governor in his stead. This revolution in favour of the 'Abbásids was, however, of no long duration. Ḥabíb, the eldest son of 'Abd al-Raḥmán, had fled on the night of his father's murder, and Ilyás caused him to be pursued, with the object of transporting him to Andalusia. Ḥabíb was captured, but the vessel which was to convey him to Spain having been detained in port by stress of weather, the partisans of independence took arms, rescued Ḥabíb, and prepared to resist Ilyás, who was marching against them at the head of an army. Under these circumstances a fortunate idea occurred to Ḥabíb. He challenged his uncle Ilyás to single combat. Ilyás hesitated, but his own soldiers compelled him to accept the challenge. He measured arms with Ḥabíb, and was laid prostrate by him with a thrust of his lance. The party of independence thus triumphed, and several years elapsed before the

The Aghlabites in Africa.

'Abbásid general, Al-Aghlab, was able to enter Ḳairawán and regain possession of Africa in the name of the Eastern Caliph. From this time forward, it must be added, Africa only nominally belonged to the 'Abbásids; for, under the Caliphate of Hárún al-Rashíd, Ibráhím, the son of Al-Aghlab, who was invested with the government of Africa, founded in that province a distinct dynasty, that of the Aghlabites.

Spanish Caliphate.

Coincidently with the revolt in Africa, the independent Caliphate of the Western Omayyads was founded in Spain. The long dissensions which had preceded the fall of that dynasty in the East, had already prepared the way for the independence of a province so distant from the centre of the empire. Every petty emir there tried to seize sovereign power for himself, and the people groaned under the consequent anarchy. Weary of these commotions, the Arabs of Spain at last came to an understanding among themselves for the election of a Caliph, and their choice fell upon the last survivor of the Omayyads, 'Abd al-Raḥmán b. Mo'áwiya, grandson of the Caliph Hishám. This prince was wandering in the deserts of Africa, pursued by his implacable enemies, but everywhere protected and concealed by the desert tribes, who pitied his misfortunes and respected his illustrious origin. A deputation from Andalusia sought him out in Africa, and offered him the Caliphate of Spain, which he accepted with joy. On 25th September, A.D. 755, 'Abd al-Raḥmán landed in the Iberian Peninsula, where he was universally welcomed, and speedily founded at Cordova the Western Omayyad Caliphate, with which this history has no further concern.

While Manṣúr was thus losing Africa and Spain, he was trying to take from the Greeks the city of Malaṭiya, which, from the importance of its situation, was looked on as the key of Asia Minor. In A.H. 139-140 (A.D. 756-757), a Moslem army of 70,000 men invested the place, and, after a vigorous siege, Malaṭiya was taken by assault. After this success the Moslems marched through Cilicia, entered Pamphylia, and cut to pieces a Greek army on the banks of the Melas. The Greeks asked and obtained a seven years' truce, which Manṣúr was the more disposed to grant because new and very serious troubles had been stirred up in his empire by certain sectaries of Khorásán, called Ráwandís. These Ráwandís, like many other Persian sectaries, admitted a number of dogmas completely foreign to Islam, such as the transmigration of souls and the incarnation of the Deity as a man. They believed, for instance, as historians assure us, that divine honours ought to be paid to the Caliph Manṣúr. They had their name from Ráwand, a city near Iṣfahán, where the sect originated. A great number of these sectaries had repaired to Háshimíya, the residence of the Caliph, and there persisted in marching in procession round his palace, as if it had been the Ka'ba. Manṣúr, refusing to receive this impious homage, caused the principal chiefs of the sect to be seized and thrown into prison. The Ráwandís immediately rose in revolt, broke open the prison doors, rescued their chiefs, and pushed their audacity so far as to besiege the Caliph in his own palace. Very fortunately for Manṣúr, the populace declared against the Ráwandís and massacred them; but from that time forward he took a dislike to the city of Háshimíya, and resolved to choose another residence. He had at first thought of fixing his place of abode at Cufa; but he remembered the fickle character of the inhabitants, and decided on founding an entirely new city on the banks of the Tigris. His choice fell upon

Foundation of Baghdád.

a spot near the ancient Ctesiphon, the capital of the Sassanids, called Baghdád. There he himself laid the first stone of the city which was to be the centre of the civilised world as long as the Caliphate lasted. A revolt, however, of some importance soon called Manṣúr's attention from the building of Baghdád. The descendants of 'Alí, who had had reason to think that the 'Abbásids were labouring for their advancement, were now cruelly undeceived. In A.H. 145 (A.D. 762-763), Mohammed Mahdí, great-grandson of Ḥosain, and surnamed Al-Nafs al-Zakíya ("the pure soul"), collected a large number of adherents at Medina, and had himself proclaimed Caliph. The governor of Cufa, 'Ísá b. Músá, received orders to march against him, and entered Arabia. The partisans of 'Alí were defeated, and Mohammed Mahdí fell in battle. But meanwhile his brother Ibráhím had gone to Baṣra, and had there succeeded in exciting a revolt, in presence of which the 'Abbásid governor had been obliged to capitulate. The adherents of 'Alí, emboldened by this success, spread themselves over 'Iráḳ, and obtained possession of several places, among which was the city of Wásiṭ. Ibráhím was already advancing towards Cufa, at the head of a strong army, when 'Ísá b. Músá, who had been hastily recalled from Arabia, threw himself in his way. A terrible conflict took place. At last Ibráhím fell, pierced by an arrow, and, in spite of the desperate efforts

dynasty, after having accomplished his work, which, as the historians assert, cost the lives of more than 600,000 men. Notwithstanding the defeat of 'Abdalláh b. 'Alí and the murder of Abú Moslim, the spirit of rebellion was not yet broken. Risings took place in Mesopotamia and to a still greater extent in Khorásán; and the Caliph's troops were repeatedly beaten by the rebels; but order was at last re-established by Manṣúr's generals, by Kházim b. Khozaima in Mesopotamia, and by Mohammed b. al-Ash'ath in Khorásán.

About the same time Africa and Spain escaped from the dominion of the Eastern Caliphate; the former for a season, the latter permanently. The cause of the revolt of Africa was as follows: As soon as Manṣúr ascended the throne, he wrote to 'Abd al-Raḥmán, announcing the death of Abú 'l-'Abbás, and requiring him to take the oath of allegiance. 'Abd al-Raḥmán sent in his adhesion to the new Caliph, and added a few presents of little value. The Caliph was so much dissatisfied that he replied by a threatening letter which excited the anger of 'Abd al-Raḥmán. He called the people together at the hour of prayer, mounted the pulpit, publicly cursed Manṣúr, and then declared his deposition from the Caliphate. He next caused a circular letter to be written, commanding all Maghrebins to refuse obedience to the Caliph; and this letter was circulated and read from the pulpit throughout the whole extent of the Maghrib (the West). A brother of 'Abd al-Raḥmán, Ilyás, saw in this revolt an opportunity of obtaining the government of Africa for himself. Seconded by many of the inhabitants of Ḳairawán, who had remained faithful to the cause of the 'Abbásids, he attacked his brother, slew him, and proclaimed himself governor in his stead. This revolution in favour of the 'Abbásids was, however, of no long duration. Ḥabíb, the eldest son of 'Abd al-Raḥmán, had fled on the night of his father's murder, and Ilyás caused him to be pursued, with the object of transporting him to Andalusia. Ḥabíb was captured, but the vessel which was to convey him to Spain having been detained in port by stress of weather, the partisans of independence took arms, rescued Ḥabíb, and prepared to resist Ilyás, who was marching against them at the head of an army. Under these circumstances a fortunate idea occurred to Ḥabíb. He challenged his uncle Ilyás to single combat. Ilyás hesitated, but his own soldiers compelled him to accept the challenge. He measured arms with Ḥabíb, and was laid prostrate by him with a thrust of his lance. The party of independence thus triumphed, and several years elapsed before the 'Abbásid general, Al-Aghlab, was able to enter Ḳairawán, and regain possession of Africa in the name of the Eastern Caliph. From this time forward, it must be added, Africa only nominally belonged to the 'Abbásids; for, under the Caliphate of Hárún al-Rashíd, Ibráhím, the son of Al-Aghlab, who was invested with the government of Africa, founded in that province a distinct dynasty, that of the Aghlabites.

The Aghlabites in Africa.

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Hádí, as may be supposed, had never been able to forget that he had narrowly escaped being supplanted by his brother. He formed a plan for excluding Hárún from the Caliphate, and transmitting the succession to his own son Ja'far. He neglected no possible means of attaining this object, and obtained the assent of his ministers, and of the principal chiefs of his army, who took the oath of allegiance to Ja'far. Only Yaḥyá b. Khálid the Barmecide, Hárún's former tutor, absolutely refused to betray the interests of his pupil. In a discussion which took place between him and the Caliph on this subject, Yaḥyá showed such firmness and boldness that Hádí resolved on his death, and Harthama b. A'yan, one of the bravest generals of the empire, had already received the order to go and take his head, when the Caliph died suddenly. One of those terrible domestic dramas had been acted of which so many were afterwards seen in the palace of the Caliphs. The mother of Hádí and Hárún was Khaizorán, a haughty and intriguing woman, whose aim it was to get the direction of affairs into her own hands, leaving Hádí only the shadow of power. Her influence over all matters of government was so well understood that her door was beset all day by a crowd of petitioners, who neglected the Caliph and preferred to address their requests to her. Hádí soon became indignant at the subordinate part which his mother wished him to play, and after a dispute on the matter, he attempted to poison her. Khaizorán, hoping to find a more submissive instrument of her will in her second son, and wishing to protect herself against fresh attempts at murder, caused Hádí to be taken unawares and smothered with cushions by two young slaves whom she had presented to him. (Rabí' I., A.H. 170, Sept. A.D. 786.)

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among the courtiers that every one found a thousand reasons for excusing his conduct. Hárún confirmed him in his post and returned to Baghdád, through which, however, he only passed, and went on to Raḳḳa on the Euphrates, a city which became his habitual residence. He did not long enjoy the repose which he went there to seek, for Nicephorus again broke the treaty of peace, and the Caliph was obliged to take the field anew. Once more Nicephorus was beaten, and so completely that he was obliged to submit to the very harsh conditions which the victor imposed on him.

Two years later, new disturbances broke out in Khorásán, where a certain Ráfi' b. Laith had revolted. Hárún set out again for that province, accompanied by his son Ma'mún. It was to be his last journey. He was attacked by a tumour in the abdomen, and struggled in vain against this malady, which carried him off a year after his departure, A.H. 193 (A.D. 808-809), just on his arrival at the city of Ṭús, the birthplace of the great epic poet of Persia, Firdausí. Hárún was only forty-seven years of age.

Amín. 6. On the death of Hárún, his minister Faḍl b. Rabí' hastened to call together all the troops of the late Caliph, and to lead them back to Baghdád, in order to place them in the hands of the new sovereign, Amín. He even led back the corps which was intended to occupy Khorásán, and which ought to have fallen to the share of Ma'mún, according to the testament of Hárún. Faḍl b. Rabí' thus committed a serious violation of the rights of Ma'mún; but he cared little for this, being chiefly desirous of winning the confidence of the new Caliph. He was quite aware, however, that in thus acting he was making Ma'mún his irreconcilable enemy; and he therefore purposed to use every endeavour to arouse against him the enmity of his brother Amín. He advised him to exclude Ma'mún from the succession, and the Caliph was weak enough to listen to him. Receiving the order to resign his government of Khorásán and to repair to Baghdád, Ma'mún was greatly perplexed; but his tutor and vizier, Faḍl b. Sahl, reanimated his courage, and pointed out to him that, if he obeyed the orders of the Caliph, certain death awaited him at Baghdád. Ma'mún resolved to hold out against Amín, and found pretexts for eluding the orders of his brother and remaining in Khorásán. Amín, in his anger, caused the testament of his father, which, as we have seen, was preserved in the Ka'ba, to be destroyed, declared, on his own authority, the rights of Ma'mún to the Caliphate to be forfeited, and caused the army to swear allegiance to his own son Músá, a child five years of age, on whom he bestowed the title of Náṭiḳ bil-Ḥaḳḳ, "He who speaks according to truth" (A.H. 194, A.D. 809-810). On hearing the news, Ma'mún, strong in the rightfulness of his claim, retaliated by suppressing the Caliph's name in all public acts. Amín immediately despatched to Khorásán an army of fifty thousand men, under the command of 'Alí b. 'Ísá. Ma'mún, on his side, raised troops among his faithful people of Khorásán, and entrusted their command to Ṭáhir b. Ḥosain, who displayed remarkable abilities in the war that ensued. In the following year, the two armies met under the walls of Ray, and victory declared for Ṭáhir. Ma'mún now no longer hesitated to take the title of Caliph. The year after, Amín placed in the field two new armies, commanded respectively by Aḥmed b. Mazyad and 'Abdalláh b. Ḥomaid b. Ḳaḥtaba. The skilful Ṭáhir b. Ḥosain succeeded in creating divisions among the troops of his adversaries, and obtained possession, without striking a blow, of the city of Ḥolwán, an advantage which placed him at the very gates of Baghdád. Ma'mún immediately sent Ṭáhir reinforcements under the orders of Harthama b. A'yan, which enabled him to maintain a firm hold on all the conquered territory, and to continue his victorious march to the capital. Reverses naturally lead to fresh reverses. One after the other the provinces fell away from Amín, and he soon found himself in possession of Baghdád alone, which was speedily invested by the troops of Ṭáhir and Harthama. That unfortunate capital, though blockaded on every side, made a desperate defence for two years. Ultimately the eastern part of the city fell into the hands of Ṭáhir, and Amín, deserted by his followers, was compelled to surrender. He resolved to treat with Harthama, as he hated Ṭáhir; but this step caused his ruin. Ṭáhir learned by his spies that Harthama was to receive the Caliph in person, and gave orders to a body of horsemen to arrest Amín as he issued from Baghdád under cover of the night. On the banks of the Tigris, Harthama awaited Amín with a boat, but scarcely had the Caliph set foot in it, when the agents of Ṭáhir poured on it a storm of arrows and stones. The boat sank, and the Caliph had to make his escape by swimming. But he was closely followed up, and had scarcely left the river when he fell into the hands of his enemies, who shut him up in a hut and went to inform Ṭáhir of the capture. The victorious general immediately ordered him to be put to death, and the order was carried out. The head of the unfortunate Amín was cut off and sent to Ma'mún, A.H. 198. It was presented to him by his vizier, Faḍl b. Sahl, surnamed Dhú 'l-Riyásatain, or "the man with two governments," because his master had committed to him both the ministry of war and the general administration. Ma'mún, on seeing the head, hid his joy beneath a feigned display of sorrow.

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God), he established himself with his guard at Sámarra, a small place situated a few leagues above Baghdád, and changed its name to Sorra-man-ra'a (He rejoices who sees it). This resolution of Mo'taṣim was destined to prove fatal to his dynasty; for it placed the Caliphs at the mercy of their Prætorians. In fact, from the time of Mo'taṣim, the Caliphate became the plaything of the Turkish guard, and its decline was continuous. Some glorious feats of arms, however, were still performed under Mo'taṣim. The sectary Bábak was at last taken by Afshín, a Turkish general of the Caliph, in the year 223 (A.D. 837-838). Bábak was carried to Baghdád, led through the city on the back of an elephant, and then delivered to the executioners, who cut off his arms and his legs. Afshín, however, was very ill rewarded for his services, for shortly afterwards the Caliph had him put to death on a charge of heresy.

The death of Ma'mún had for the moment suspended hostilities with Constantinople; under Mo'taṣim the war was rekindled. A valiant Greek general, Manuel, who had incurred the displeasure of the Emperor Theophilus, took refuge with the Caliph, who eagerly welcomed him and gave him a command. Manuel began by reducing Khorásán, which had risen in revolt, and Mo'taṣim was so well satisfied with him that he thought of employing him against his own countrymen. This was precisely what Theophilus dreaded, and he took measures accordingly to bring back the banished general to his side. He sent an ambassador to Mo'taṣim, under pretence of ransoming some Greek prisoners; but the real object of his mission, which he contrived to communicate to Manuel, was the recall of that general. Manuel, feigning great animosity against his country, himself asked to be allowed to lead a Moslem army into Cappadocia. The Caliph granted his request, and sent with him his own son Wáthiḳ billáh. But, as soon as they reached the frontiers of Cappadocia, Manuel confessed to the young prince that his intention was to return to Constantinople, and quitted the army. Theophilus, taking advantage of the confusion into which the departure of Manuel had thrown the Moslems, made an incursion into Syria, laid waste that province as far as Zabaṭra, and returned loaded with booty. At the news of this disaster, Mo'taṣim assembled a formidable army, estimated at more than two hundred thousand men, penetrated into Asia Minor, beat the Greeks, and took the city of Amorium, which he ordered to be razed to the ground. A revolt which broke out at Baghdád in favour of his nephew 'Abbás, the son of Ma'mún, compelled the Caliph to turn back. Mo'taṣim had the unfortunate 'Abbás arrested, and he was soon after found dead in his prison. Mo'taṣim survived him only four years. He died at Sorra-man-ra'a, in A.H. 227 (A.D. 841-842).

Wáthiḳ. 9. His son Wáthiḳ, who succeeded him, showed himself no less intolerant on the doctrinal question of the uncreated Koran. He carried his zeal to such a point that, on the occasion of an exchange of Greek against Moslem prisoners, in the year 231 (A.D. 845-846), he ordered that all the Moslem captives who would not declare their belief that the Koran was a human work, should be left in the hands of the enemy. The reign of Wáthiḳ billáh was not otherwise marked by any very striking events. He died in 232 (A.D. 846-847), after a reign of five years. As he had appointed no successor before his death, the principal personages of the state at first cast their eyes on his son Mohammed; but they had scarcely saluted him with the title of Caliph, when they changed their purpose, and offered the supreme power to Motawakkil 'ala 'lláh (He who trusts to God), brother of Wáthiḳ. This prince was therefore elected in the same year in which Wáthiḳ died.

10. The first act of Motawakkil was an atrocious cruelty. He seized Mohammed b. 'Abd al-Melik, his brother's vizier, who had always been his enemy, and ordered him to be placed in a furnace bristling within with iron points, which was then raised to a red heat. The Caliph looked on at the agonies of his victim, incessantly repeating: "Pity is a weakness." This had been the favourite maxim of the unfortunate vizier. An impostor named Mohammed b. Faraj had set himself up as a prophet, giving out that he was Moses risen from the dead. By means of this gross fabrication, he had contrived to attract twenty-seven followers. The Caliph had him seized, and condemned him to perpetual imprisonment; but first he compelled each of the followers of Mohammed to give the pretended prophet ten blows on the head with his fist; and the poor wretch expired under the hands of his own disciples. (A.H. 235, A.D. 849-850.) Motawakkil.

In the year of his elevation to the Caliphate, Motawakkil had regulated the succession to the empire in his own family, by designating as future Caliphs his three sons, Montaṣir billáh (He who seeks help in God), Mo'tazz billáh (Strong through God), and Mowayyad billáh (Assisted by God). In acting thus, his object was to protest against the tendency of his predecessors to favour the house of 'Alí, and to guard against the attainment of the Caliphate by any member of that house. Motawakkil displayed the most extreme hatred for the descendants of the Prophet. He even went so far as to destroy the chapel erected over the tomb of Ḥosain at Kerbelá, and forbade the Shí'ites to visit the spot. Not content with attacking the liberty and the property of the descendants of 'Alí, he insulted their belief, by taking buffoons into his pay, whose business it was to turn the person of 'Alí into mockery. He also persecuted the Christians and the Jews; excluding them from all public employments, and obliging them to send their children to Moslem schools. In the year 237, a revolt broke out in Armenia. The Caliph sent the Turk Bugha against the rebels; but they met him with a vigorous resistance, and it was four years before peace was restored to the province. During that time the Greeks effected a descent on Egypt, and Damietta was taken and burned. Motawakkil caused Damietta to be fortified, and transferred his own residence to Damascus, doubtless that he might be able to keep a closer watch on the proceedings of the Byzantines. He soon thought himself strong enough to take the offensive, and poured his Turkish soldiery into Asia Minor, where they encountered the same Manuel who had been formerly received at the court of Mo'taṣim. After an alternation of successes and reverses, both Moslems and Greeks retired from the conflict. Motawakkil then returned to his residence at Sorra-man-ra'a, and there caused a magnificent quarter to be built, which he called Ja'fariyya.[1] There he gave himself up to debaucheries; till at last, during one of his orgies, he was murdered by a Turkish soldier named Waṣíf, who had been bribed to the deed by his own son Montaṣir billáh (A.H. 247, A.D. 861-862).

11. On the very night of his father's assassination Montaṣir had himself proclaimed Caliph. The conspirators among the Turkish soldiery compelled him to deprive his two brothers, Mo'tazz and Mowayyad, who were not agreeable to them, of their rights of succession. Montaṣir did not long enjoy the fruits of his crime. He died five months after, by poison, it is said. Montaṣir.

12. The Turkish soldiery, which now arrogated to itself the mastery over the Caliphate, chose in succession to Montaṣir his cousin Aḥmed, who took the title of Mosta'ín Mosta'ín

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party of Moḳtadir prevailed, and his rival was put to death. Moḳtadir, however, was too young to exercise any real power; he was governed by his eunuchs. He was, besides, a man of feeble character, and looked on helplessly at the death-struggle of the empire, upon which calamities of every kind now poured in. The Greeks invaded Mesopotamia. A truce was concluded with them; but the Carmathians then recommenced their disorders in Syria. The indolence of the Caliph, and his inaction in the face of this danger, alienated all hearts from him; and the eunuch Múnis, the principal chief of his party, took the lead in deposing him and proclaiming in his stead his brother Ḳáhir billáh (Victorious through God), in the year 317 (A.D. 929-930). Ḳáhir, however, having refused to distribute a donative to the army on the occasion of his accession, a counter-revolution took place, and Moḳtadir, who had been imprisoned, was taken from his dungeon and replaced on the throne, only three days after his deposition. Favoured by these disturbances, the governor of Mosul, Náṣir al-Daula, declared himself independent, and founded definitively the dynasty of the Ḥamdánites; thus causing an additional dismemberment of the empire. The Carmathians in their turn, under the guidance of a new chief, Abú Ṭáhir, obtained possession of Mecca, and carried off the celebrated black stone of the Ka'ba, which they did not restore till very long afterwards. Meanwhile the eunuch Múnis had been disgraced. He withdrew at first to Mosul, to the court of Náṣir al-Daula; but it was to raise an army and march upon Baghdád, where the Caliph had again fixed his abode. The object of Múnis was not to attack the Caliph, but only to take vengeance on his personal enemies. Moḳtadir was induced by evil counsellors to make a sally against Múnis. His troops were put to the rout, and he himself fell on the field of battle, in the year 320 (A.D. 932).

The Fátimites.

With the reign of Moḳtadir is connected one of the greatest events in the history of the Caliphate, the foundation of the Fátimite dynasty, which reigned, first in the Maghrib and then in Egypt, for nearly three centuries. The first of this family who put forward any pretensions to the Caliphate was 'Obaid Alláh, surnamed the Mahdí, or Messiah of the followers of 'Alí, who gave himself out as a direct descendant of 'Alí, through his wife Fáṭima, the daughter of Mohammed, whence the name of Fátimite. It seems to be proved that 'Obaid Alláh was really descended from a certain 'Abdalláh b. Maimún el-Ḳaddáḥ, the founder of the Ismailian sect, of which the Carmathians were only a branch. This 'Obaid Alláh had himself become pontiff of the Ismailians. As early as the Caliphate of Moktafí, one of 'Obaid Alláh's missionaries, named Abú 'Abdalláh, had succeeded in gaining numerous partisans in the province of Africa, then subject to the Aghlabites, and the victories of this missionary had wrested Eastern Africa from the family of Aghlab when Moḳtadir ascended the throne. 'Obaid Alláh then repaired to his new realm (A.H. 303), and founded the city of Mahdíya, which he made his capital. He tried also, but without success, to seize Egypt; the conquest of that country was reserved for one of his successors, Mo'izz li-dín-illáh. 'Obaid Alláh died two years after Moḳtadir, leaving to his son Ḳáim an empire already sufficiently powerful to cause uneasiness to the 'Abbásids, to the Omayyads of Spain, and to all the Christian princes whose states bordered on the Mediterranean.

The last 'Abbásids. Ḳáhir.

19. Ḳáhir billáh, on being raised anew to the throne after the death of his brother Moḳtadir, still bore ill-will to his patrons, and tried to free himself from their guardianship. The emirs of his court dethroned him a second time and put out his eyes. One of his nephews was then proclaimed Caliph under the name of Rádí

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billáh (Content through God). This prince, who was entirely governed by those about his person, created, in favour of a certain Abúbekr Mohammed b. Ráiḳ, the office of Amír al-Omará, or Emir of the Emirs, which nearly corresponds to that of Mayor of the Palace among the Franks.[1] The Amír al-Omará was charged with the administration of civil and military affairs. He also acted as the Caliph's deputy in sacerdotal functions, and was named next after him in the public prayers. Thenceforth the Caliphate was no longer anything but an empty shadow. During the reigns of Ḳáhir and Rádí, the Carmathians became more audacious than ever. The Amír al-Omará was obliged to purchase from them the freedom of pilgrimage to Mecca at the price of a disgraceful treaty. Thus the Caliphate found itself almost reduced to the province of Baghdád. Khorásán, Transoxiana, Kirmán, and Persia were in the hands of independent sovereigns, the Sámánids, the Búyids, and a prince named Washimgír. The Ḥamdánites possessed Mesopotamia; the Sájites, Armenia; Egypt was under the rule of the Ikhshídites; Arabia was held by the Carmathians; Africa, as we have seen, had become the prey of the Fáṭimites. The single transient success obtained by Rádí was the capture of Mosul in A.H. 328 (A.D. 939-40); and even this success he owed to the Turk Bejkem, who had succeeded Mohammed b. Ráiḳ as Amír al-Omará.

Rádí died in the following year, and was succeeded by Mottaḳí lilláh (He who fears God). From his very accession, this prince saw himself exposed to the attacks of a certain Al-Barídí, who had carved out for himself a principality in Chaldæa, and who now laid siege to Baghdád. Náṣir al-Daula, prince of Mosul, who had been reinstated in his government, offered an asylum to Mottaḳí; put his troops at his disposal, and succeeded in repelling Al-Barídí. In return he obtained the office of Amír al-Omará. But there were other competitors for that post. Turun, a former lieutenant of Bejkem, protested sword in hand against the choice of the Caliph, and threatened Baghdád. Ikhshíd, sovereign of Egypt, offered Mottaḳí a refuge in his states; but Turun, fearing to see the Caliph obtain such powerful support, found means to entice him to his tent, and had his eyes put out, A.H. 333 (A.D. 944-945). Mottaḳí.

As successor to Mottaḳí, Turun chose Mostakfí billáh (He who places his whole trust in God). This prince, like his predecessors, was a mere puppet in the hands of his ministers. A new Amír al-Omará, Zírak b. Shírzád, made himself so hateful to the people of Baghdád by his deeds of violence and rapacity that they besought the help of the Búyids. Aḥmed, the third prince of that dynasty, entered Baghdád, overthrew Zírak, and took his place under the title of Mo'izz al-Daula. Mostakfí soon had enough of this new master, and ventured to conspire against him. The plot was discovered, and Mo'izz al-Daula had the eyes of the Caliph put out. There were now at Baghdád three Caliphs who had been dethroned and blinded—Ḳáhir, Mottaḳí, and Mostakfí. Mo'izz al-Daula thought for a moment of restoring the illusory title of Caliph to the descendants of 'Alí. He feared, however, lest this should lead to the recovery by the Caliphs of their former supremacy, and his choice fell on a son of Moḳtadir under the name of Motí' lilláh (He who obeys God). Reserving to himself all the powers and revenues of the Caliph, he allowed Motí' merely a secretary and a moderate pension. The prince of Mosul, who began to think his possessions threatened by the neighbourhood of Mo'izz, entered on a struggle with him and tried to wrest Baghdád from him; but he failed, and was obliged to Mostakfí. Motí'.

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[1] See Defrémery, *Mémoire sur les Emirs al-Oméra.* Paris, 1848.

GENEALOGICAL TABLE OF THE 'ABBÁSID CALIPHS DOWN TO THE FALL OF BAGHDÁD.

'Abbás.
'Abdalláh.
'Alí.
Mohammed.
Ibráhím. 1. Abú 'l-'Abbás. 2. Mansúr.
3. Mahdí.
4. Hádí. 5. Hárún al-Rashíd.
6. Amín. 7. Ma'mún. 8. Mo'tasim.
Mohammed. 9. Wáthik. 10. Motawakkil.
12. Mosta'ín. 14. Mohtadí.
Mowaffak. 11. Montasir. 15. Mo'tamid. 13. Mo'tazz.
16. Mo'tadid.
19. Káhir. 18. Moktadir. 17. Moktafí.
22. Mostakfí.
Isḥák. 23. Motí'. 21. Mottakí. 20. Rádí.
24. Táí'.
25. Kádir.
26. Káim.
Mohammed Dhakhírat al-Dín.
27. Moktadí.
28. Mostazhir.
31. Moktafí. 29. Mostarshid.
32. Mostanjid. 30. Ráshid.
33. Mostadí'.
34. Násir.
35. Záhir.
36. Mostansir.
37. Mosta'sim.

SECT. III.—SKETCH OF THE INSTITUTIONS AND CIVILIZATION OF THE EASTERN CALIPHATE.

Mohammed had begun to bestow political unity on Arabia; but he had done still more: he had given her the Koran, as the starting-point and base of the future civilization of Islam. It was for the preservation and the better understanding of the sacred text that the first believers were led to create grammar and lexicography, and to make collections of the poems of their own and former times, those "witnesses of the meaning of words," as the Arabs call them. To elucidate questions of dogma they created theology. Jurisprudence, in like manner, issued from the Koran, and the historical sciences at first gathered around it. As early as the first century of the Flight, schools were founded in 'Irák, at Basra and at Cufa, in which all the questions to which the study of the Koran gave rise were stated, and answered in different ways. Natural science and mathematics were less directly concerned with the sacred book, and were consequently neglected during the whole period of the Omayyad dynasty. They only began to be cultivated when, under the 'Abbásids, the study of philosophy led to the use of translations from the Greek. The institutions of Islam were developed, no doubt, as new wants made themselves felt, in proportion to the extension of the empire; but they were nevertheless founded on the first arrangements made by the Prophet, and handed down by him in the Koran.

Political and social institutions.

Under the first four Caliphs these institutions continued in a rudimentary state. The Caliph (*Khalífa*, substitute or successor) was elected by the Moslem community; and, after receiving from all its members the oath of fidelity (*Bai'a*) which they were bound to take, united the temporal and spiritual powers in his own hands. He was at the same time high priest, ruler, and judge. He was compelled, however, by the very extent of the empire to delegate his powers to those agents (*'Ámil*, plural *'Ommál*) whom he commissioned to represent him in the provinces. The State revenues, which entered the public treasury (*Bait al-mál*), were composed—(1) of the tithe, or tax for the poor (*Zakát*), which every Moslem was bound to pay; (2) of the fifth, raised on all booty taken in war, the rest being divided among the warriors; (3) of the poll-tax (*Jizya*) and the land-tax (*Kharáj*), which only affected non-Moslem subjects. The Caliph administered the revenues of the State at his own pleasure, applying them to the necessities of war, to public works, to the payment of officials, to the support of the poor, and to the distribution of the annual pensions, in which every Moslem had originally a right to share. The State could possess landed property. Under 'Omar I. we find that the pasture land belonging to the State supported not less than forty thousand camels and horses. To 'Omar I. was due the regulation of the poll-tax by a fixed scale. The rich, whether Christians or Jews, paid four dínárs (about thirty-two shillings) yearly; people of the middle class, two dínárs; the poor, one dínár. Besides this payment in money, the subject-races had to make contributions in kind, intended for the support of the troops. The land-tax consisted of a general rent in proportion to the extent, character, and fertility of the lands possessed by the conquered.

The Díwán.

As the sums produced by these different imposts were often very considerable, it became necessary, as early as the Caliphate of 'Omar I., to create a special office, charged with the accounts of their expenditure. Its organization was borrowed by 'Omar from the Persians, and it retained its Persian name of Díwán, a term afterwards applied to all government offices. The Arabs at that time being too illiterate for such employment, the task of keeping the registers of the Díwán was entrusted to Greeks, Copts, and Persians. 'Omar also gave his attention to the apportionment of the individual pensions of the Faithful. Every one received a larger or smaller sum according to the greater or less nearness of his connexion with the family, or the tribe, of the Prophet. Thus 'Áisha, who had been the favourite wife of Mohammed, received a yearly pension of twelve thousand dirhems;[1] the other widows of the Prophet only received ten thousand. The Háshimites and Mottalibites, that is, the members of the Prophet's family, also received ten thousand dirhems. The Emigrants and the Defenders, or those citizens of Mecca and Medina who had been the first to embrace Islam, had five thousand dirhems; and that was the sum which 'Omar I. allotted to himself.[2] For every other Moslem of full age, the pension varied from 4000 to 300 dirhems. We can easily understand what an influence the hope of this pension must have exerted on the conquered races, and how much it must

[1] The dirhem was equivalent to one franc.

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Sect. III.—Sketch of the Institutions and Civilization of the Eastern Caliphate.

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Simultaneously with the accession of the 'Abbásids, Persian influence began to preponderate. The Persian, Khálid b. Barmak, was entrusted with the administration of the finances (*Díwán al-Kharáj*) by As-Saffáh, who was also the first Caliph who transferred the burden of public affairs from himself to a Prime Minister (*Wazír*, whence, in European languages, the term *Vizier*). The title of Wazír was unknown to the Omayyads. The office of Prime Minister was of Persian origin. It existed till the time of the Caliph Rádí, when that of Amír al-Omará was substituted for it. When the Caliphs had fallen under the tutelage of the Búyids, it was the latter who chose Viziers, leaving to the Caliphs only Secretaries (*Rayís al-Ruwasá*). Under the Seljúk Sultans the Caliphs were again permitted to choose their own Viziers.

Prime Minister.

The institution of the office of Vizier was not the least among the causes of the decadence of the Eastern Caliphate. The 'Abbásids gradually became unaccustomed to the exercise of power and the management of affairs, and thus lost all direct influence over their subjects. Besides the Minister of Finance and the Vizier, the 'Abbásids created another important office, that of Postmaster-General (*Sáhib al-Baríd*), whose duty it was to collect at a central office all the information which arrived from the provinces, and to transmit it to the Prime Minister. Thus the administrative services were greatly extended under the 'Abbásids. They were subdivided as follows:—1. *Díwán al-Kharáj*, or Ministry of Finance; 2. *Díwán al-Diyá'*, or Bureau of State property; 3. *Díwán al-Zimám*, Registry Office or Exchequer Office; 4. *Díwán al-Jond*, or Ministry of War; 5. *Nazar al-Mazálim*, or Court of Appeal; 6. *Díwán al-Mawálí wal-Ghilmán*, or Bureau of the freedmen and slaves of the Caliphs; 7. *Díwán Zimám al-Nafakát*, or Office of Expenditure; 8. *Díwán al-Baríd*, or Office of the Posts; 9. *Díwán al-Rasáil*, or Office of Correspondence; 10. *Díwán al-Taukí'*, or Office of the Imperial Seal, and of the registration of official documents. There were also offices for the despatch and reception of official documents, and for the inspection of weights and measures.

Administrative services.

Organization of the State.

We cannot better conclude this brief summary of the institutions of the Caliphate than by giving a sketch of the organization of the State, according to the Moslem authors themselves.

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The supreme chief received the title of Caliph, or of Commander of the Faithful (Amír al-Mo'minín). He united in his own person all the powers of the State; his Ministers and all public functionaries acted only by virtue of a commission from him. They, like all other Moslems, were at the mercy of the Caliph, who had power of life and death over them. As spiritual chief, the Caliph was also the supreme judge in questions of dogma. In theory he held his powers by the free choice of the majority of Moslems; but, when he had once received their oath of allegiance, he became their absolute master. The first condition of eligibility to the Caliphate was to belong to the tribe of Koraish. In Moslem belief, the subjects of the Caliph owed him obedience and aid so long as he should fulfil his duties with exactness. These consisted in maintaining the principles of religion, in administering justice scrupulously, in defending the territory and assuring its safety, in carrying on war for the subjugation of the infidels, and in spending the public revenue in conformity to the law. If the Caliph failed in the performance of his duty, rebellion against him became lawful.

Ministers.

The Ministers might be absolute or dependent. If dependent, they simply executed the orders of their sovereign. If absolute, they took his place, and exercised all the powers of a Caliph except that they could not, at least in theory, designate any successor to the reigning Caliph. It was only to the Caliph himself that they were responsible for their actions.

Prefects.

The Prefects, when once appointed, whether by the Caliph or the Vizier, became so many petty sovereigns, and, legally, owed an account of their actions only to the Caliph, or to his Prime Minister, when the latter was absolute.

Generals.

The Generals were appointed either by the Caliph or by the Vizier, or lastly by the Prefect, when only a local war was in question. They were sometimes invested with very extensive powers, such as those of concluding treaties of peace, of administering justice, and of dividing the booty. The General, in his turn, appointed the officers (*Nakíbs*) and under-officers (*'Arífs*). It was a general order that infidels, before hostilities against them were opened, should be summoned to embrace the faith, or to submit by capitulation. The conversion of infidels was valid, even when effected sword in hand, on the field of battle, and the new convert became inviolable in person and property. On the other hand, every infidel taken prisoner was sold as a slave, with his wife and children. He might even be put to death. Apostates were never to be spared; they were put to death, and their property confiscated.

Cadis.

Justice was administered by Cadis, appointed either by the Caliph, by the Vizier, or by the Prefect. To be eligible as a Cadi (*Kádi*), it was requisite that a man should be—1. A male and of respectable age; 2. In full possession of his mental and physical faculties; 3. A free man; 4. A Moslem; 5. Of good moral character; 6. Acquainted with the principles of the law and their application. The duties of the Cadi were to examine into the disputes and lawsuits brought before him; to enforce the execution of his judgments; to name judicial councils for the administration of the goods of minors, madmen, etc.; to administer the mortmain property of mosques and schools (*wakf*, plural *wokúf*); to watch over the execution of wills; to inflict due legal penalties on those guilty of crimes or misdemeanours;[1] and to inspect the highways and public buildings. When any locality possessed no Imám, or public officiator at the mosque, it was the Cadi who performed this duty. The assistants of the Cadi were Notaries (*Shohúd*), Secretaries (*Omaná*), and Deputies (*Náyibín*). If the Cadi died, his subordinates lost their offices *ipso facto*. On the other hand, the death of a Caliph did not nullify the powers of the Cadi; but it was necessary that he should be confirmed by the new sovereign.

Court of Appeal.

The Court of Appeal (*Nazar al-Mazálim*) was instituted to take cognizance of those causes in which the parties concerned appealed from the judgment of the Cadi. The sittings of this court were presided over by the Caliph in person. It was established by the Omayyad 'Abd al-Melik. The last Caliph who sat in public to examine appeal cases was Mohtadí. After him a special judge was appointed to the function of president of the Court of Appeal.

Inspectors.

Besides the Judges there were Inspectors (*Mohtasib*), charged with the police of the markets and the care of morals. The Mohtasib's duty was to take care that weights and measures were not falsified, and that buyers were not deceived as to the quality of the goods sold. He had the power of inflicting summary punishment on delinquents, but only in the case of flagrant offences. If the person charged denied the facts, he was to be brought before the Cadi. As regards morals, the Mohtasib took care that widows and divorced women should not remarry before the expiration of the legal period prescribed by the

[1] The principal offences were—apostasy, neglect of religious duties, refusal to pay taxes, theft, adultery, outrages, and murder. The penalties were imprisonment, fines, corporal punishment, and death.

Simultaneously with the accession of the 'Abbásids, Persian influence began to preponderate. The Persian, Khálid b. Barmak, was entrusted with the administration of the finances (*Díwán al-Kharáj*) by As-Saffáh, who was also the first Caliph who transferred the burden of public affairs from himself to a Prime Minister (*Wazír*, whence, in European languages, the term *Vizier*). The title of Wazír was unknown to the Omayyads. The office of Prime Minister was of Persian origin. It existed till the time of the Caliph Rádí, when that of Amír al-Omará was substituted for it. When the Caliphs had fallen under the tutelage of the Búyids, it was the latter who chose Viziers, leaving to the Caliphs only Secretaries (*Rayís al-Ruwasá*). Under the Seljúk Sultans the Caliphs were again permitted to choose their own Viziers.

Prime Minister.

The institution of the office of Vizier was not the least among the causes of the decadence of the Eastern Caliphate. The 'Abbásids gradually became unaccustomed to the exercise of power and the management of affairs, and thus lost all direct influence over their subjects. Besides the Minister of Finance and the Vizier, the 'Abbásids created another important office, that of Postmaster-General (*Ṣáḥib al-Baríd*), whose duty it was to collect at a central office all the information which arrived from the provinces, and to transmit it to the Prime Minister. Thus the administrative services were greatly extended under the 'Abbásids. They were subdivided as follows:—1. *Díwán al-Kharáj*, or Ministry of Finance; 2. *Díwán al-Ḍiyá'*, or Bureau of State property; 3. *Díwán al-Zimám*, Registry Office or Exchequer Office; 4. *Díwán al-Jond*, or Ministry of War; 5. *Nazar al-Mazálim*, or Court of Appeal; 6. *Díwán al-Mawálí wal-Ghilmán*, or Bureau of the freedmen and slaves of the Caliphs; 7. *Díwán Zimám al-Nafakát*, or Office of Expenditure; 8. *Díwán al-Baríd*, or Office of the Posts; 9. *Díwán al-Rasáil*, or Office of Correspondence; 10. *Díwán al-Taukí'*, or Office of the Imperial Seal, and of the registration of official documents. There were also offices for the despatch and reception of official documents, and for the inspection of weights and measures.

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Under the 'Abbásids it seemed for a moment that the Shí'ite doctrines were about to triumph. We know, in fact, that the founder of that dynasty gave himself out as the heir of the house of 'Alí. But reasons of State prevailed, and the 'Abbásids, false to their first professions, on the whole supported orthodoxy. Under their reign were established the four orthodox sects—Málikite, Hanafite, Sháfi'ite, and Hanbalite, which even at this day divide between them the whole Moslem world. They are named after their founders—Málik, Abú Hanífa, Sháfi'í, and Ibn Hanbal. These sects only differ from each other on a few points of civil and religious jurisprudence. They agree on questions of dogma. It was not, however, without difficulty that orthodoxy succeeded in obtaining the victory. Under Ma'mún and other Caliphs several doctors, as we have seen, were persecuted for believing that the Koran was the uncreated word of God. From the time of Motawakkil, however, orthodoxy regained the upper hand. Still, this reaction would not have lasted long, in face of the advance in science which marked the accession of Ma'mún to power, if the orthodox had had no other defensive weapons than material force and the assent of the majority. As philosophy made its way in Islam, thanks to the translations from Greek authors, which were made principally during the Caliphate of Ma'mún, it called forth in men's minds a movement of scientific curiosity which might have been fatal to orthodoxy. In the tenth century of our era a society of encyclopedists was formed at Basra, who, under the name of Ikhwán al-Safá, or Brothers of Purity, put forth a number of very curious treatises, in which all sorts of physical and metaphysical questions were discussed and resolved in a scientific manner.[1] There is no doubt that these lucid and attractive writings would have led to a great religious revolution, if the orthodox had not understood the danger of their position, and applied themselves also to the study of philosophy, for the purpose of employing it in the service of the faith. It was thus that, towards the middle of the tenth century, a certain Abú 'l-Hasan al-Ash'arí, a descendant of that Abú Músá al-Ash'arí who had formerly acted the part of arbitrator in the dispute between Mo'áwiya and 'Alí, struck out a system in which religion appeared to be reconciled with philosophy; a system which was naturally sure to attract all commonplace minds—that is to say, the greater number. Ash'arism, or philosophic theology (Kalám), was adopted with enthusiasm by the triumphant orthodox doctors, and thenceforth pure philosophy and the heterodox sects ceased to extend their influence.[2]

The orthodox sects.

Ash'arí.

The creation, however, of this philosophical theology had not done away with all dangers for orthodoxy. We have seen above that the Shí'a were divided into several sects, each holding for one of the direct descendants of 'Alí, and paying him the reverence due to a deity. One of these sects, called the Ismailian, because it acknowledged Ismá'íl, the seventh Imám or Pontiff of the posterity of 'Alí, as its chief, was the source of the greatest disorders in the Moslem empire, and was not far from being triumphant in Asia, as it was for a long time in Egypt. The Ismailians, like all the other Shí'ites, believed in the coming of a Messiah, whom they called the Mahdí, and who, according to them, was one day to appear on earth, in order to establish the reign of justice and equity, and to take vengeance on the oppressors of the family of 'Alí. They also believed in a God of far more elevated character than the God of the Koran, one who was unapproachable by human reason, and who had created the universe, not directly, but by the intermediate action of a sublime being, the Universal Reason, produced by an act of God's will. The Universal Reason, in its turn, had produced the Universal Soul, which, on its part, had given birth to primitive Matter, to Space, and to Time. These five principles were the causes of the universe. Man, emanating from them, had a tendency to reascend towards his source. The chief end of his being was to attain to perfect union with the Universal Reason.[3] But, left to himself, man would have been powerless to attain this end. The Universal Reason and the Universal Soul therefore became incarnate among men, in order to guide them towards the light. These incarnations were no other than the prophets in all ages, and, in the last period, the Imáms of the posterity of 'Alí. In the second half of the ninth century, a Persian, born in Susiana and named 'Abdalláh b. Maimún al-Kaddáh, nourished the dream of destroying Islam, and thought these doctrines, suitably modified, likely to be highly useful in carrying out his purpose. He devised a system at once religious, philosophical, political, and social, in which, as he thought, all beliefs were to meet and mingle, but—and in this consisted its originality—a system so graduated to suit different degrees of intelligence, that the whole world should become one vast Masonic association. The chief of the Ismailians, the Imám Ismá'íl, having died, 'Abdalláh asserted that his son Mohammed b. Ismá'íl was to succeed him as the founder of this new religion, which it was 'Abdalláh's mission to announce to the world. Since the creation of the world, as 'Abdalláh asserted, there had been six religious periods, each marked by an incarnation of the Universal Reason in the person of a prophet. Adam, Noah, Abraham, Moses, Jesus, and Mohammed had been the prophets of these periods. Their mission had been to invite men to accept more and more perfect forms of religion. The seventh and last religion, and the most perfect of all, was that of Mohammed b. Ismá'íl, the true Messiah. The Ismailians, as may be imagined, readily embraced the theories of 'Abdalláh. In addressing other sects and religions, 'Abdalláh used special arguments with each. With the philosophers he dwelt on the philosophical principles of his doctrine. The conversion of Christians, Moslems, or Jews, was a more difficult task. 'Abdalláh had established several degrees of initiation, and it was only by slow degrees, and with the most minute precautions, that he gained a mastery over the mind of the future proselyte. His curiosity was first aroused by allegorical interpretations of the Old Testament, the Gospels, and the Koran, and by proposing to him religious problems which could not be solved by any of the existing religions. The solution of these problems was not to be given to him till he should have signed a compact, and sworn never to reveal the mysteries with which he was made acquainted. If he took this pledge, he thenceforward belonged, body and soul, to the sect; and woe to him if he made any attempt to withdraw himself from the authority of his chiefs! The compact signed, the newly-initiated disciple had to make a certain payment, which went to swell the treasury of the sect. The secret society

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School of 'Irák.

In 'Irák another school of law was formed, which is distinguished from that of Medina by a greater degree of independence. While the lawyers of Medina held strictly to the Koran, the traditions of the Prophet, and the 'Áthár, those of 'Irák admitted, in addition to these, the deductive or analogical method (*Kiyás*), according to which it was lawful to create precedents, provided there was no departure from the spirit of the sacred book, from the traditions of the Prophet, or from the corresponding decisions of the first four Caliphs. Ibn Abí Laila, who filled the office of judge in 'Irák under the caliphate of Manṣúr, was one of the first to apply this system. His renown, however, was eclipsed by that of his contemporary Abú Ḥaníſa, who worked out a complete system of jurisprudence, with which his name has continued to be connected (Hanifite law). Fifty years after the death of Abú Ḥaníſa, Sháfi'í, a pupil of Málik, appeared at Baghdád, and founded in his turn an intermediate system, in which he endeavoured to hold an equal balance between the purely traditional and the deductive methods. The fourth system reputed orthodox is that of Ibn Ḥanbal, a pupil of Sháfi'í. Ibn Ḥanbal strove above all things to bring back religious observances to their primitive purity. His doctrine was a kind of puritanism. As may be supposed, each of these systems has been subsequently developed and commented on in a multitude of works, even the names of which it is impossible to enumerate. In order, however, to give some idea of what a Moslem treatise on jurisprudence is, we shall point out the principal subjects contained in it. It treats successively—1. Of Purification (ablutions commanded by the law, purification of women, circumcision, etc.); 2. Of Prayer as commanded by the law; 3. Of Funerals; 4. Of Tithe and Almsgiving; 5. Of the legal Fast; 6. Of the Pilgrimage to Mecca; 7. Of Commercial and other transactions; 8. Of Inheritance; 9. Of Marriage and Divorce; 10. Of the Faith; 11. Of Crimes and Misdemeanours; 12. Of Justice; 13. Of the Imámate or spiritual power, and of the Caliphate or temporal power. It is thus a complete code, religious, civil, penal, and governmental, that Moslem treatises on jurisprudence set before us; a code which embraces and foresees all the circumstances both of public and private life.

Science and letters.

The development of science and literature runs parallel with the development of law. Before the time of Mohammed the Arabs had been distinguished only by a rare poetical talent. Islam was the signal for the springing up of all the sciences and of literature. While the study of the dogmas and ordinances of the Koran was producing theology and jurisprudence, the necessity of preserving the exact text of the sacred book, and of teaching the new converts the language of the Prophet, was giving birth to grammar and lexicography. The first school of grammar was established at Baṣra. The first attempts at grammar are generally attributed to a certain Abú 'l-Aswad al-Do'alí, who was tutor to the children of Ziyád, the brother of Mo'áwiya. According, however, to some authors, the honour of having discovered the first elements of grammar ought to be attributed to a Persian, named 'Abd al-Raḥmán b. Hormúz. Be this as it may, a foreign influence must be recognized at the very commencement of this science. The vowel marks, for instance, were imitated from those of the Syriac. The division of the parts of speech into nouns, verbs, and particles was indirectly borrowed from Greek grammar. Yet the Moslems, once in possession of the principles of grammar, knew how to develop and apply them in an admirable manner. A perfect galaxy of grammarians arose in the track of Abú 'l-Aswad; a rival school to that of Baṣra was established at Cufa, and grammar attained its highest degree of perfection under the first 'Abbásids; as is shown by the voluminous treatise of Síbawaihi, known under the name of *Kitáb*,[1] or the Book *par excellence*.

Grammar.

Lexicography.

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School of 'Irák. In 'Irák another school of law was formed, which is distinguished from that of Medina by a greater degree of independence. While the lawyers of Medina held strictly to the Koran, the traditions of the Prophet, and the 'Áthár, those of 'Irák admitted, in addition to these, the deductive or analogical method (*Kiyás*), according to which it was lawful to create precedents, provided there was no departure from the spirit of the sacred book, from the traditions of the Prophet, or from the corresponding decisions of the first four Caliphs. Ibn Abí Laila, who filled the office of judge in 'Irák under the caliphate of Manṣúr, was one of the first to apply this system. His renown, however, was eclipsed by that of his contemporary Abú Ḥanífa, who worked out a complete system of jurisprudence, with which his name has continued to be connected (Ḥanifite law). Fifty years after the death of Abú Ḥanífa, Sháfi'í, a pupil of Málik, appeared at Baghdád, and founded in his turn an intermediate system, in which he endeavoured to hold an equal balance between the purely traditional and the deductive methods. The fourth system reputed orthodox is that of Ibn Ḥanbal, a pupil of Sháfi'í. Ibn Ḥanbal strove above all things to bring back religious observances to their primitive purity. His doctrine was a kind of puritanism. As may be supposed, each of these systems has been subsequently developed and commented on in a multitude of works, even the names of which it is impossible to enumerate. In order, however, to give some idea of what a Moslem treatise on jurisprudence is, we shall point out the principal subjects contained in it. It treats successively—1. Of Purification (ablutions commanded by the law, purification of women, circumcision, etc.); 2. Of Prayer as commanded by the law; 3. Of Funerals; 4. Of Tithe and Almsgiving; 5. Of the legal Fast; 6. Of the Pilgrimage to Mecca; 7. Of Commercial and other transactions; 8. Of Inheritance; 9. Of Marriage and Divorce; 10. Of the Faith; 11. Of Crimes and Misdemeanours; 12. Of Justice; 13. Of the Imámate or spiritual power, and of the Caliphate or temporal power. It is thus a complete code, religious, civil, penal, and governmental, that Moslem treatises on jurisprudence set before us; a code which embraces and foresees all the circumstances both of public and private life.

Science and letters. The development of science and literature runs parallel with the development of law. Before the time of Mohammed the Arabs had been distinguished only by a rare poetical talent. Islam was the signal for the springing up of all the sciences and of literature. While the study of the dogmas and ordinances of the Koran was producing theology and jurisprudence, the necessity of preserving the exact text of the sacred book, and of teaching the new converts the language of the Prophet, was giving birth to grammar and lexicography. The first school of grammar was established at Baṣra. The first attempts at grammar are generally attributed to a certain Abú 'l-Aswad al-Do'alí, who was tutor to the children of Ziyád, the brother of Mo'áwiya. According, however, to some authors, the honour of having discovered the first elements of grammar ought to be attributed to a Persian, named 'Abd al-Raḥmán b. Hormúz. Be this as it may, a foreign influence must be recognized at the very commencement of this science. The vowel marks, for instance, were imitated from those of the Syriac. The division of the parts of speech into nouns, verbs, and particles was indirectly borrowed from Greek grammar. Yet the Moslems, once in possession of the principles of grammar, knew how to develop and apply them in an admirable manner. A perfect galaxy of grammarians arose in the track of Abú 'l-Aswad; a rival school to that of Baṣra was established at Cufa, and grammar attained its highest degree of perfection under the first 'Abbásids; as is shown by the voluminous treatise of Síbawaihi, known under the name of *Kitáb*,[1] or the Book *par excellence*.

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Commerce. With an empire so vast as that of the Moslems, we may easily conceive how extensive their commerce and industry must have been. Commerce had at all times been held in honour by the Arabs. Long before the days of Mohammed, the Koraish annually sent caravans, laden with all the products of Yemen, into Syria. Maritime commerce also was already flourishing in Chaldæa in the 5th century of our era. The city of Hîra was frequented by ships coming from the Red Sea, from India, and even from China. Obolla was the emporium for the merchandise of India. It was principally thither that teakwood was brought, which served for the construction of ships and houses. Thus the Arabs, when they conquered Chaldæa, found maritime commerce in full activity there, and took advantage of it. Under the 'Abbâsids Basra supplanted Hira and Obolla, and became the principal port. The history of Sindibâd (Sinbad the Sailor) shows how active foreign commerce was under the 'Abbâsids, and with what courage the Arab sailors confronted danger. Moslem colonies were established all along the coasts of Persia and India, and Moslem voyagers did not fear to venture as far as the China Seas. On the West, the commercial movement was not less active. Caravans laden with the products of Spain left Tangier, traversed the whole of Northern Africa, and reached Syria, Arabia, and Mesopotamia. Others passed through Asia Minor, Armenia, Persia, Khorâsân, and Turkestân, as far as the frontiers of China, while the route of others again was along the eastern coast of Africa, whence they brought back ivory and black slaves. Thus the silks of China, and the spices, camphor, steel, and precious woods of India, were poured into the empire, while the Moslems exported their glass, their dates, their cotton stuffs, their refined sugar, and their wrought tools, to those countries. The manufacture of glass was an industry of old standing among them. The glass of Syria was celebrated, and we know that flint-glass and enamels were also made at Baghdâd. Dates were cultivated principally in the neighbourhood of Basra, and also in Persia and Khûzistân. Refined sugar also came from the coast of Persia. As regards steel, the manufacture of armour and weapons was the speciality of the people of 'Irâk, of Bahrain, of 'Omân, and of Yemen. The Syrians had the credit of forging excellent sword-blades. In Syria too were made mirrors of polished steel. The weaving of various stuffs formed an important branch of industry. The striped stuffs of Yemen, and the tissues of Baghdâd, Herât, Tawwaj, and Fasá, enjoyed a high repute. Damascus was renowned for the silk fabrics which have taken their name from that city. The silks of Yemen, of Egypt, and of Cufa, had also a high reputation. Tunis produced gauze and muslin figured with gold. Egypt manufactured brocade, Armenia supplied satin. The carpet manufacture under the Caliphs had already reached the excellence which it has maintained to our own days. At that time the carpets most valued came from Fársistán and Ṭabaristán. Jewellery and trinkets found numerous outlets, as may be supposed. This traffic was principally carried on in the East by the Jews.

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The manufacture of paper was carried on very extensively, a fact which is easily explained when we think of the literary activity of the Moslems. The Arabs originally used parchment. For this, after the conquest of Egypt, they substituted papyrus, which was itself supplanted by paper, when the Arabs had opened communications with China. Paper mills were established in several of the provinces, and at Baghdâd itself. Simultaneously with the appearance of this precious substance, the art of binding became one of the most flourishing industries, as did also the trades of the shoemaker, the saddler, and the dyer, etc. etc. Retail commerce, lastly, undertook the distribution of the products of agriculture and industry. In almost all the cities of the empire markets were held, where the fruiterer and grocer (*Bakkâl*), the butcher (*Jazâr*), the armourer (*Saikal*), the bookseller (*Warrâk*), and the druggist and perfumer (*'Aṭṭâr*), offered their wares for sale.[3] (ST. G.)

PART III.—THE KORAN.

THE Koran (Ko'rân) is the foundation of Islam. It is the sacred book of more than a hundred millions of men, some of them nations of immemorial civilization, by all whom it is regarded as the immediate word of God. And since the use of the Koran in public worship, in schools and otherwise, is much more extensive than, for example, the reading of the Bible in most Christian countries, it has been truly described as the most widely-read book in existence. This circumstance alone is sufficient to give it an urgent claim on our attention, whether it suit our taste and fall in with our religious and philosophical views or not. Besides, it is the work of Mohammed, and as such is fitted to afford a clue to the spiritual development of that most successful of all prophets and religious personalities. It must be owned that the first perusal leaves on a European an impression of chaotic confusion,—not that the book is so very extensive, for it is not quite so large as the New Testament. This impression can in some degree be modified only by the application of a critical analysis with the assistance of Arabian tradition.

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convenient to employ some one else whenever he had anything to write. After the flight to Medina (A.D. 622) we are told that short pieces—chiefly legal decisions—were taken down immediately after they were revealed, by an adherent whom he summoned for the purpose; so that nothing stood in the way of their publication. Hence it is probable that in Mecca, where the art of writing was commoner than in Medina, he had already begun to have his oracles committed to writing. That even long portions of the Koran existed in written form from an early date may be pretty safely inferred from various indications; especially from the fact that in Mecca the Prophet had caused insertions to be made, and pieces to be erased in his previous revelations. For we cannot suppose that he knew the longer súras by heart so perfectly that he was able after a time to lay his finger upon any particular passage. In some instances, indeed, he may have relied too much on his memory. For example, he seems to have occasionally dictated the same súra to different persons in slightly different terms. In such cases, no doubt, he may have partly intended to introduce improvements; and so long as the difference was merely in expression, without affecting the sense, it could occasion no perplexity to his followers. None of them had literary pedantry enough to question the consistency of the divine revelation on that ground. In particular instances, however, the difference of reading was too important to be overlooked. Thus the Koran itself confesses that the unbelievers cast it up as a reproach to the Prophet that God sometimes substituted one verse for another (xvi. 103). On one occasion, when a dispute arose between two of his own followers as to the true reading of a passage which both had received from the Prophet himself, Mohammed is said to have explained that the Koran was revealed in seven forms. In this apparently genuine dictum seven stands, of course, as in many other cases, for an indefinite but limited number. But one may imagine what a world of trouble it has cost the Moslem theologians to explain the saying in accordance with their dogmatic beliefs. A great number of explanations are current, some of which claim the authority of the Prophet himself; as, indeed, fictitious utterances of Mohammed play throughout a conspicuous part in the exegesis of the Koran. One very favourite, but utterly untenable interpretation is that the "seven forms" are seven different Arabic dialects.

Abrogated readings.

When such discrepancies came to the cognisance of Mohammed it was doubtless his desire that only one of the conflicting texts should be considered authentic; only he never gave himself much trouble to have his wish carried into effect. Although in theory he was an upholder of verbal inspiration, he did not push the doctrine to its extreme consequences; his practical good sense did not take these things so strictly as the theologians of later centuries. Sometimes, however, he did suppress whole sections or verses, enjoining his followers to efface or forget them, and declaring them to be "abrogated." A very remarkable case is that of the two verses in liii., when he had recognised three heathen goddesses as exalted beings, possessing influence with God. (*Supra*, p. 549.)

Abrogated laws.

So much for abrogated readings; the case is somewhat different when we come to the abrogation of laws and directions to the Moslems, which often occurs in the Koran. There is nothing in this at variance with Mohammed's idea of God. God is to him an absolute despot, who declares a thing right or wrong from no inherent necessity but by his arbitrary fiat. This God varies his commands at pleasure, prescribes one law for the Christians, another for the Jews, and a third for the Moslems; nay, he even changes his instructions to the Moslems when it pleases him. Thus, for example, the Koran contains very different directions, suited to varying circumstances, as to the treatment which idolaters are to receive at the hands of believers. But Mohammed showed no anxiety to have these superseded enactments destroyed. Believers could be in no uncertainty as to which of two contradictory passages remained in force; and they might still find edification in that which had become obsolete. That later generations might not so easily distinguish the "abrogated" from the "abrogating" did not occur to Mohammed, whose vision, naturally enough, seldom extended to the future of his religious community. Current events were invariably kept in view in the revelations. In Medina it called forth the admiration of the Faithful to observe how often God gave them the answer to a question whose settlement was urgently required at the moment. The same naïveté appears in a remark of the Caliph 'Othmán about a doubtful case: 'If the Apostle of God were still alive, methinks there had been a Koran passage revealed on this point." Not unfrequently the divine word was found to coincide with the advice which Mohammed had received from his most intimate disciples. "Omar was many a time of a certain opinion," says one tradition, "and the Koran was then revealed accordingly."

Contents of the Koran.

The contents of the different parts of the Koran are extremely varied. Many passages consist of theological or moral reflections. We are reminded of the greatness, the goodness, the righteousness of God as manifested in Nature, in history, and in revelation through the prophets, especially through Mohammed. God is magnified as the One, the All-powerful. Idolatry and all deification of created beings, such as the worship of Christ as the Son of God, are unsparingly condemned. The joys of heaven and the pains of hell are depicted in vivid sensuous imagery, as is also the terror of the whole creation at the advent of the last day and the judgment of the world. Believers receive general moral instruction, as well as directions for special circumstances. The lukewarm are rebuked, the enemies threatened with terrible punishment, both temporal and eternal. To the sceptical the truth of Islam is held forth; and a certain, not very cogent, method of demonstration predominates. In many passages the sacred book falls into a diffuse preaching style, others seem more like proclamations or general orders. A great number contain ceremonial or civil laws, or even special commands to individuals down to such matters as the regulation of Mohammed's harem. In not a few, definite questions are answered which had actually been propounded to the Prophet by believers or infidels. Mohammed himself, too, repeatedly receives direct injunctions, and does not escape an occasional rebuke. One súra (i.) is a prayer, two (cxiii., cxiv.) are magical formulas. Many súras treat of a single topic, others embrace several.

Narratives.

From the mass of material comprised in the Koran—and the account we have given is far from exhaustive—we should select the histories of the ancient prophets and saints as possessing a peculiar interest. The purpose of Mohammed is to show from these histories how God in former times had rewarded the righteous and punished their enemies. For the most part the old prophets only serve to introduce a little variety in point of form, for they are almost in every case facsimiles of Mohammed himself. They preach exactly like him, they have to bring the very same charges against their opponents, who on their part behave exactly as the unbelieving inhabitants of Mecca. The Koran even goes so far as to make Noah contend against the worship of certain false gods, mentioned by name, who were worshipped by the Arabs of Mohammed's time. In an address which is put in the mouth of Abraham (xxvi. 75 *sqq.*) the reader quite forgets that it is Abraham, and not Mohammed (or God himself) who is

convenient to employ some one else whenever he had anything to write. After the flight to Medina (A.D. 622) we are told that short pieces—chiefly legal decisions—were taken down immediately after they were revealed, by an adherent whom he summoned for the purpose; so that nothing stood in the way of their publication. Hence it is probable that in Mecca, where the art of writing was commoner than in Medina, he had already begun to have his oracles committed to writing. That even long portions of the Koran existed in written form from an early date may be pretty safely inferred from various indications; especially from the fact that in Mecca the Prophet had caused insertions to be made, and pieces to be erased in his previous revelations. For we cannot suppose that he knew the longer súras by heart so perfectly that he was able after a time to lay his finger upon any particular passage. In some instances, indeed, he may have relied too much on his memory. For example, he seems to have occasionally dictated the same súra to different persons in slightly different terms. In such cases, no doubt, he may have partly intended to introduce improvements; and so long as the difference was merely in expression, without affecting the sense, it could occasion no perplexity to his followers. None of them had literary pedantry enough to question the consistency of the divine revelation on that ground. In particular instances, however, the difference of reading was too important to be overlooked. Thus the Koran itself confesses that the unbelievers cast it up as a reproach to the Prophet that God sometimes substituted one verse for another (xvi. 103). On one occasion, when a dispute arose between two of his own followers as to the true reading of a passage which both had received from the Prophet himself, Mohammed is said to have explained that the Koran was revealed in seven forms. In this apparently genuine dictum seven stands, of course, as in many other cases, for an indefinite but limited number. But one may imagine what a world of trouble it has cost the Moslem theologians to explain the saying in accordance with their dogmatic beliefs. A great number of explanations are current, some of which claim the authority of the Prophet himself; as, indeed, fictitious utterances of Mohammed play throughout a conspicuous part in the exegesis of the Koran. One very favourite, but utterly untenable interpretation is that the "seven forms" are seven different Arabic dialects.

Abrogated readings.

When such discrepancies came to the cognisance of Mohammed it was doubtless his desire that only one of the conflicting texts should be considered authentic; only he never gave himself much trouble to have his wish carried into effect. Although in theory he was an upholder of verbal inspiration, he did not push the doctrine to its extreme consequences; his practical good sense did not take these things so strictly as the theologians of later centuries. Sometimes, however, he did suppress whole sections or verses, enjoining his followers to efface or forget them, and declaring them to be "abrogated." A very remarkable case is that of the two verses in liii., when he had recognised three heathen goddesses as exalted beings, possessing influence with God. (*Supra*, p. 549.)

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Stylistic weaknesses.

On the whole, while many parts of the Koran undoubtedly have considerable rhetorical power, even over an unbelieving reader, the book, æsthetically considered, is by no means a first-rate performance. To begin with what we are most competent to criticize, let us look at some of the more extended narratives. It has already been noticed how vehement and abrupt they are where they ought to be characterized by epic repose. Indispensable links, both in expression and in the sequence of events, are often omitted, so that to understand these histories is sometimes far easier for us than for those who heard them first, because we know most of them from better sources. Along with this, there is a great deal of superfluous verbiage; and nowhere do we find a steady advance in the narration. Contrast in these respects the history of Joseph (xii.) and its glaring improprieties, with the admirably-conceived and admirably-executed story in Genesis. Similar faults are found in the non-narrative portions of the Koran. The connexion of ideas is extremely loose, and even the syntax betrays great awkwardness. Anacolutha are of frequent occurrence, and cannot be explained as conscious literary devices. Many sentences begin with a "when" or "on the day when" which seems to hover in the air, so that the commentators are driven to supply a "think of this" or some such ellipsis. Again, there is no great literary skill evinced in the frequent and needless harping on the same words and phrases; in xviii., for example, "till that" (*hattá idhá*) occurs no fewer than eight times. Mohammed, in short, is not in any sense a master of style. This opinion will be endorsed by any European who reads through the book with an impartial spirit and some knowledge of the language, without taking into account the tiresome effect of its endless iterations. But in the ears of every pious Moslem such a judgment will sound almost as shocking as downright atheism or polytheism.

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short sentences with tolerably pure but rapidly-changing rhymes. The oaths, too, with which many of them begin, were largely used by the soothsayers. Some of these oaths are very uncouth and hard to understand, some of them perhaps were not meant to be understood, for indeed all sorts of strange things are met with in these chapters. Here and there Mohammed speaks of visions, and appears even to see angels before him in bodily form. There are some intensely vivid descriptions of the resurrection and the last day which must have exercised a demonic power over men who were quite unfamiliar with such pictures. Other pieces paint in glowing colours the joys of heaven and the pains of hell. However, the súras of this period are not all so wild as these; and those which are conceived in a calmer mood appear to be the oldest. Yet, one must repeat, it is exceedingly difficult to make out any strict chronological sequence. For instance, it is by no means certain whether the beginning of xcvi. is really, what a widely-circulated tradition calls it, the oldest part of the whole Koran. That tradition goes back to the Prophet's favourite wife 'Áisha; but as she was not born at the time when the revelation is said to have been made, it can only contain at the best what Mohammed told her years afterwards, from his own not very clear recollection, with or without fictitious additions. And, moreover, there are other pieces mentioned by others as the oldest. In any case xcvi. 1 *sqq.* is certainly very early. According to the traditional view, which appears to be correct, it treats of a vision in which the Prophet receives an injunction to recite a revelation conveyed to him by the angel. It is interesting to observe that here already two things are brought forward as proofs of the omnipotence and care of God: one is the creation of man out of a seminal drop—an idea to which Mohammed often recurs; the other is the then recently introduced art of writing, which the Prophet instinctively seizes on as a means of propagating his doctrines. It was only after Mohammed encountered obstinate resistance that the tone of the revelations became thoroughly passionate. In such cases he was not slow to utter terrible threats against those who ridiculed the preaching of the unity of God, of the resurrection, and of the judgment. His own uncle Abú Lahab had rudely repelled him, and in a brief special súra (cxi.) he and his wife are consigned to hell. The súras of this period form almost exclusively the concluding portions of the present text. One is disposed to assume, however, that they were at one time more numerous, and that many of them were lost at an early period.

Since Mohammed's strength lay in his enthusiastic and fiery imagination rather than in the wealth of ideas and clearness of abstract thought on which exact reasoning depends, it follows that the older súras, in which the former qualities have free scope, must be more attractive to us than the later. In the súras of the second period the imaginative glow perceptibly diminishes; there is still fire and animation, but the tone becomes gradually more prosaic. As the feverish restlessness subsides, the periods are drawn out, and the revelations as a whole become longer. The truth of the new doctrine is proved by accumulated instances of God's working in nature and in history; the objections of opponents, whether advanced in good faith or in jest, are controverted by arguments; but the demonstration is often confused or even weak. The histories of the earlier prophets, which had occasionally been briefly touched on in the first period, are now related, sometimes at great length. On the whole, the charm of the style is passing away.

The Fátiha.

There is one piece of the Koran, belonging to the beginning of this period, if not to the close of the former, which claims particular notice. This is i., the Lord's Prayer of the Moslems, and beyond dispute the gem of the Koran. The words of this súra, which is known as *al-fátiha* ("the opening one") are as follows:—

(1) In the name of God, the compassionate compassioner. (2) Praise be [literally "is"] to God, the Lord of the worlds, (3) the compassionate compassioner, (4) the Sovereign of the day of judgment. (5) Thee do we worship and of Thee do we beg assistance. (6) Direct us in the right way; (7) in the way of those to whom Thou hast been gracious, on whom there is no wrath, and who go not astray.

The thoughts are so simple as to need no explanation; and yet the prayer is full of meaning. It is true that there is not a single original idea of Mohammed's in it. Several words and turns of expression are borrowed directly from the Jews, in particular the designation of God as the "Compassioner," *Raḥmán*. This is simply the Jewish *Raḥmáná*, which was a favourite name for God in the Talmudic period. Mohammed seems for a while to have entertained the thought of adopting *al-Raḥmán* as a proper name of God, in place of *Alláh*, which was already used by the heathens.[1] This purpose he ultimately relinquished, but it is just in the súras of the second period that the use of *Raḥmán* is specially frequent. It was probably in the first súra also that Mohammed first introduced the formula, "In the name of God," etc. It is to be regretted that this prayer must lose its effect through too frequent use, for every Moslem who says his five prayers regularly—as the most of them do—repeats it not less than twenty times a day.

Raḥmán.

Latest Meccan súras.

The súras of the third Meccan period, which form a pretty large part of our present Koran, are almost entirely prosaic. Some of the revelations are of considerable extent, and the single verses also are much longer than in the older súras. Only now and then a gleam of poetic power flashes out. A sermonizing tone predominates. The súras are very edifying for one who is already reconciled to their import, but to us at least they do not seem very well fitted to carry conviction to the minds of unbelievers. That impression, however, is not correct, for in reality the demonstrations of these longer Meccan súras appear to have been peculiarly influential for the propagation of Islam. Mohammed's mission was not to Europeans, but to a people who, though quick-witted and receptive, were not accustomed to logical thinking, while they had outgrown their ancient religion.

Medina súras.

When we reach the Medina period it becomes, as has been indicated, much easier to understand the revelations in their historical relations, since our knowledge of the history of Mohammed in Medina is tolerably complete. In many cases the historical occasion is perfectly clear, in others we can at least recognize the general situation from which they arose, and thus approximately fix their time. There still remains, however, a remnant, of which we can only say that it belongs to Medina.

The style of this period bears a pretty close resemblance to that of the latest Meccan period. It is for the most part pure prose, enriched by occasional rhetorical embellishments. Yet even here there are many bright and impressive passages, especially in those sections which may be regarded as proclamations to the army of the faithful. For the Moslems, Mohammed has many different messages. At one time it is a summons to do battle for the faith; at another, a series of reflexions on recently experienced success or misfortune, or a rebuke for their weak faith; or an exhortation to virtue, and so on. He often addresses himself to the "doubters," some of whom vacillate between faith and unbelief, others make a pretence of faith, while others

[1] Since in Arabic also the root رحم signifies "to have pity," the Arabs must have at once perceived the force of the new name.

short sentences with tolerably pure but rapidly-changing rhymes. The oaths, too, with which many of them begin, were largely used by the soothsayers. Some of these oaths are very uncouth and hard to understand, some of them perhaps were not meant to be understood, for indeed all sorts of strange things are met with in these chapters. Here and there Mohammed speaks of visions, and appears even to see angels before him in bodily form. There are some intensely vivid descriptions of the resurrection and the last day which must have exercised a demonic power over men who were quite unfamiliar with such pictures. Other pieces paint in glowing colours the joys of heaven and the pains of hell. However, the súras of this period are not all so wild as these; and those which are conceived in a calmer mood appear to be the oldest. Yet, one must repeat, it is exceedingly difficult to make out any strict chronological sequence. For instance, it is by no means certain whether the beginning of xcvi. is really, what a widely-circulated tradition calls it, the oldest part of the whole Koran. That tradition goes back to the Prophet's favourite wife 'Áisha; but as she was not born at the time when the revelation is said to have been made, it can only contain at the best what Mohammed told her years afterwards, from his own not very clear recollection, with or without fictitious additions. And, moreover, there are other pieces mentioned by others as the oldest. In any case xcvi. 1 *sqq.* is certainly very early. According to the traditional view, which appears to be correct, it treats of a vision in which the Prophet receives an injunction to recite a revelation conveyed to him by the angel. It is interesting to observe that here already two things are brought forward as proofs of the omnipotence and care of God: one is the creation of man out of a seminal drop—an idea to which Mohammed often recurs; the other is the then recently introduced art of writing, which the Prophet instinctively seizes on as a means of propagating his doctrines. It was only after Mohammed encountered obstinate resistance that the tone of the revelations became thoroughly passionate. In such cases he was not slow to utter terrible threats against those who ridiculed the preaching of the unity of God, of the resurrection, and of the judgment. His own uncle Abú Lahab had rudely repelled him, and in a brief special súra (cxi.) he and his wife are consigned to hell. The súras of this period form almost exclusively the concluding portions of the present text. One is disposed to assume, however, that they were at one time more numerous, and that many of them were lost at an early period.

Since Mohammed's strength lay in his enthusiastic and fiery imagination rather than in the wealth of ideas and clearness of abstract thought on which exact reasoning depends, it follows that the older súras, in which the former qualities have free scope, must be more attractive to us than the later. In the súras of the second period the imaginative glow perceptibly diminishes; there is still fire and animation, but the tone becomes gradually more prosaic. As the feverish restlessness subsides, the periods are drawn out, and the revelations as a whole become longer. The truth of the new doctrine is proved by accumulated instances of God's working in nature and in history; the objections of opponents, whether advanced in good faith or in jest, are controverted by arguments; but the demonstration is often confused or even weak. The histories of the earlier prophets, which had occasionally been briefly touched on in the first period, are now related, sometimes at great length. On the whole, the charm of the style is passing away.

The Fátiha.

There is one piece of the Koran, belonging to the beginning of this period, if not to the close of the former, which claims particular notice. This is i., the Lord's Prayer of the Moslems, and beyond dispute the gem of the Koran. The words of this súra, which is known as *al-fátiha* ("the opening one") are as follows:—

(1) In the name of God, the compassionate compassioner. (2) Praise be [literally "is"] to God, the Lord of the worlds, (3) the compassionate compassioner, (4) the Sovereign of the day of judgment. (5) Thee do we worship and of Thee do we beg assistance. (6) Direct us in the right way; (7) in the way of those to whom Thou hast been gracious, on whom there is no wrath, and who go not astray.

The thoughts are so simple as to need no explanation; and yet the prayer is full of meaning. It is true that there is not a single original idea of Mohammed's in it. Several words and turns of expression are borrowed directly from the Jews, in particular the designation of God as the "Compassioner," *Rahmán*. This is simply the Jewish *Rahmáná*, which was a favourite name for God in the Talmudic period. Mohammed seems for a while to have entertained the thought of adopting *al-Rahmán* as a proper name of God, in place of *Alláh*, which was already used by the heathens.[1] This purpose he ultimately relinquished, but it is just in the súras of the second period that the use of *Rahmán* is specially frequent. It was probably in the first súra also that Mohammed first introduced the formula, "In the name of God," etc. It is to be regretted that this prayer must lose its effect through too frequent use, for every Moslem who says his five prayers regularly—as the most of them do—repeats it not less than twenty times a day.

Latest Meccan súras.

The súras of the third Meccan period, which form a pretty large part of our present Koran, are almost entirely prosaic. Some of the revelations are of considerable extent, and the single verses also are much longer than in the older súras. Only now and then a gleam of poetic power flashes out. A sermonizing tone predominates. The súras are very edifying for one who is already reconciled to their import, but to us at least they do not seem very well fitted to carry conviction to the minds of unbelievers. That impression, however, is not correct, for in reality the demonstrations of these longer Meccan súras appear to have been peculiarly influential for the propagation of Islam. Mohammed's mission was not to Europeans, but to a people who, though quick-witted and receptive, were not accustomed to logical thinking, while they had outgrown their ancient religion.

Medina súras.

When we reach the Medina period it becomes, as has been indicated, much easier to understand the revelations in their historical relations, since our knowledge of the history of Mohammed in Medina is tolerably complete. In many cases the historical occasion is perfectly clear, in others we can at least recognize the general situation from which they arose, and thus approximately fix their time. There still remains, however, a remnant, of which we can only say that it belongs to Medina.

The style of this period bears a pretty close resemblance to that of the latest Meccan period. It is for the most part pure prose, enriched by occasional rhetorical embellishments. Yet even here there are many bright and impressive passages, especially in those sections which may be regarded as proclamations to the army of the faithful. For the Moslems, Mohammed has many different messages. At one time it is a summons to do battle for the faith; at another, a series of reflexions on recently experienced success or misfortune, or a rebuke for their weak faith; or an exhortation to virtue, and so on. He often addresses himself to the "doubters," some of whom vacillate between faith and unbelief, others make a pretence of faith, while others

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Hafṣa, which, however, was soon afterwards destroyed by Merwán, the governor of Medina. The destruction of the earlier codices was an irreparable loss to criticism; but, for the essentially political object of putting an end to controversies by admitting only one form of the common book of religion and of law, this measure was necessary.

The result of these labours is in our hands; as to how they were conducted we have no trustworthy information, tradition being here too much under the influence of dogmatic presuppositions. The critical methods of a modern scientific commission will not be expected of an age when the highest literary education for an Arab consisted in ability to read and write. It now seems to me highly probable that this second redaction took this simple form: Zaid read off from the codex which he had previously written, and his associates, simultaneously or successively, wrote one copy each to his dictation. It certainly cannot have been by chance that, according to sure tradition, they wrote exactly four copies. Be that as it may, it is impossible now to distinguish in the present form of the book what belongs to the first redaction from what is due to the second.

In the arrangement of the separate sections, a classification according to contents was impracticable because of the variety of subjects often dealt with in one súra. A chronological arrangement was out of the question, because the chronology of the older pieces must have been imperfectly known, and because in some cases passages of different dates had been joined together. Indeed, systematic principles of this kind were altogether disregarded at that period. The pieces were accordingly arranged in indiscriminate order, the only rule observed being to place the long súras first and the shorter towards the end, and even that was far from strictly adhered to. The short opening súra is so placed on account of its superiority to the rest, and two magical formulæ are kept for a sort of protection at the end; these are the only special traces of design. The combination of pieces of different origin may proceed partly from the possessors of the codices from which Zaid compiled his first complete copy, partly from Zaid himself. The individual súras are separated simply by the superscription—"In the name of God, the compassionate Compassioner," which is wanting only in the ninth. The additional headings found in our texts (the name of the súra, the number of verses, etc.) were not in the original codices, and form no integral part of the Koran.

It is said that 'Othmán directed Zaid and his associates, in cases of disagreement, to follow the Koraish dialect; but, though well attested, this account can scarcely be correct. The extremely primitive writing of those days was quite incapable of rendering such minute differences as can have existed between the pronunciation of Mecca and that of Medina.

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'Othmán's Koran was not complete. Some passages are evidently fragmentary; and a few detached pieces are still extant which were originally parts of the Koran, although they have been omitted by Zaid. Amongst these are some which there is no reason to suppose Mohammed desired to suppress. Zaid may easily have overlooked a few stray fragments, but that he purposely omitted anything which he believed to belong to the Koran is very unlikely. It has been conjectured that in deference to his superiors he kept out of the book the names of Mohammed's enemies, if they or their families came afterwards to be respected. But it must be remembered that it was never Mohammed's practice to refer explicitly to contemporary persons and affairs in the Koran. Only a single friend, his adopted son Zaid (xxxiii. 37), and a single enemy, his uncle Abú Lahab (cxi.)—and these for very special reasons—are mentioned by name; and the name of the latter has been left in the Koran with a fearful curse annexed to it, although his son had embraced Islam before the death of Mohammed. So, on the other hand, there is no single verse or clause which can be plausibly made out to be an interpolation by Zaid at the instance of Abúbekr, 'Omar, or 'Othmán. Slight clerical errors there may have been, but the Koran of 'Othmán contains none but genuine elements,—though sometimes in very strange order.

Of the four exemplars of 'Othmán's Koran, one was kept in Medina, and one was sent to each of the three metropolitan cities, Cufa, Baṣra, and Damascus. It can still be pretty clearly shown in detail that these four codices deviated from one another in points of orthography, in the insertion or omission of a *wa* ("and"), and such-like minutiæ; but these variations nowhere affect the sense. All later manuscripts are derived from these four originals.

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MÖHLER, JOHANN ADAM (1796-1838), Roman Catholic theologian, was born at the village of Igersheim in Würtemberg on 6th May 1796, and, after studying philosophy and theology in the Lyceum at Ellwangen, entered the Wilhelmstift in the university of Tübingen in 1817. Ordained to the priesthood in 1819, he was appointed to a curacy at Riedlingen, but speedily returned as "repetent" to Tübingen, where he became privat-docent in 1822, extraordinary professor of theology in 1826, and ordinary in 1828. The controversies excited by his *Symbolik* (1832) proved so unpleasant that in 1835 he accepted a call to the university of Munich. In 1838 he was appointed to the deanery of Würzburg, but died shortly afterwards (12th April 1838).

Möhler wrote *Die Einheit in der Kirche* (Tübingen, 1825); *Athanasius der Grosse u. d. Kirche seiner Zeit im Kampfe m. d. Arianismus* (2 vols., Mainz, 1827); *Symbolik, oder Darstellung der dogmatischen Gegensätze der Katholiken u. Protestanten nach ihren öffentlichen Bekenntnissschriften* (Mainz, 1832; 8th ed., 1871-72; Eng. transl. by J. B. Robertson, 1843); and *Neue Untersuchungen der Lehrgegensätze zwischen den Katholiken u. Protestanten* (1834). His *Gesammelte Schriften u. Aufsätze* were edited by Döllinger in 1839; his *Patrologie* by Reithmayr, also in 1839; and a *Biographie* by Wörner was published at Ratisbon in 1866. It is with the *Symbolik* that his name is chiefly associated; the interest excited by it in Protestant circles is shown by the fact that within two years of its appearance it had elicited three replies of considerable importance, those namely of Baur, Marheineke, and Nitzsch. But, although characterized by abundant learning and acuteness, as well as by considerable breadth of spiritual sympathy, and thus a stimulative and suggestive work, it cannot be said to have been accepted by Catholics themselves as embodying an accurate objective view of the actual doctrine of their church. The liberal school of thought of which Möhler was a prominent exponent was discouraged in official circles, while Protestants, on the other hand, complain that the author has failed to grasp the vast significance of the Reformation as a great movement in the spiritual history of mankind, while expending needless pains on an exposition of the doctrinal shortcomings, inconsistencies, and contradictions of the individuals who were its leaders.

MOHR, KARL FRIEDRICH (1806-1879), a philosopher whose greatest claims to scientific distinction are as yet, though indubitable, only partially admitted, was the son of a well-to-do druggist in Coblentz, and was born 4th November 1806. Being a delicate child, he received much of his early education at home, in great part in his father's laboratory. To this may be traced much of the skill he showed in devising instruments and methods of analysis which are still in common use in chemical and pharmaceutical laboratories. At the age of 21 he studied chemistry under Gmelin, and, after five years spent in Heidelberg, Berlin, and Bonn, returned with the degree of Ph.D. to join his father's establishment. On the death of his father in 1840 he succeeded to the business, retiring from it for scientific leisure in 1857. Serious pecuniary losses led him at the age of 57 to become a privat-docent in Bonn, where he was soon after appointed, by the direct influence of the emperor, extraordinary professor of pharmacy. In private and domestic life he was a man of singularly winning manners, intensely fond of music and poetry, for the latter of which he showed wonderful memory. But his uncompromising spirit—perhaps we might even in some cases say his wrongheadedness—in matters of scientific and theological authority had raised such a host of enemies that even royal influence could not secure his further advancement. Although he stood at the very head of the scientific pharmacists of Germany, his name was deliberately omitted from the list of the commission entrusted with the preparation of the *Pharmacopœia Germanica*. Yet in that work many of his ideas and processes were incorporated by the very men who had previously denounced them. He died in October 1879.

Mohr's best-known work is his *Lehrbuch der chemisch-analytischen Titrirmethode* (1855), which has already run through many editions, and which was specially commended by Liebig. His improvements in methods of chemical analysis occupy a long series of papers extending over some fifty years. He also published a number of physical papers on subjects such as Hail, St. Elmo's Fire, Ground-ice, &c., and a curious notice of the earliest mention of Ozone. He shows that Homer, on four different occasions, mentions the sulphurous smell produced by lightning, and employs the very word from which the name of Ozone was long afterwards coined. In 1866 appeared his *Geschichte der Erde, eine Geologie auf neuer Grundlage*, which has obtained a wide circulation.

But he will be remembered in future times mainly on account of a paper, *Ueber die Natur der Wärme*, published in 1837, which unfortunately has not yet appeared in full in an English translation. The history of this paper is remarkable. It was refused admission into *Poggendorff's Annalen*, and was then sent to Baumgartner of Vienna, in whose *Zeitschrift für Physik*, &c., it was at once published. As no proof-sheets reached Mohr, he concluded that his paper had been lost or rejected, and contented himself with publishing a short analysis in the *Annalen der Pharmacie*, of which he was an editor. This analysis, it is only fair to say, though probably prepared by the author himself, gives a very inadequate idea of the scope and merit of the paper. In 1864 Dr. Akin unearthed the paper from the forgotten pages of the *Zeitschrift*, and the author was enabled to reprint it, with notes, while the recent discussions as to the history of Conservation of Energy were still being carried on. Along with it he issued a number of other papers of greatly inferior merit.

Unless some still earlier author should be discovered, there can be no doubt that Mohr is to be recognized as the first to enunciate in its generality what we now call "conservation of energy." The thesis of his paper must be stated in his own words,—"Besides the 54 known chemical elements, there is in the physical world one agent only, and this is called Kraft (energy).[1] It may appear, according to circumstances, as motion, chemical affinity, cohesion, electricity, light, and magnetism; and from any one of these forms it can be transformed into any of the others." Even now, after nearly half a century of rapid advance in science, it would be difficult to improve this statement except by inserting, as regards transformation of energy, some such guarding expression as "in whole or in part." But if Mohr had inserted this, he might have had claims to the "dissipation of energy" also. Mohr's starting-point appears to have been the discovery (by Forbes) of the polarization of radiant heat. He goes through the whole of the then range of physics, pointing out the explanation of each experimental result as a transformation of energy, mentioning even the electric currents produced by electro-magnetic induction as a transformation of the energy required to draw the coil from the magnet—one of the earlier methods used by Joule for quantitative determinations. His numerical results, based on data quoted from various books, are, it is

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MOHL, JULES (1800-1876), Orientalist, was born at Stuttgart 25th October 1800, and educated for the Lutheran Church at Tübingen; but his inclinations carried him from theology through Hebrew to Oriental studies, and in 1823 he betook himself to Paris, at that time under De Sacy the great European school of Eastern letters. He soon acquired reputation, and from 1826 to 1833 was nominally professor at Tübingen, with permission to continue his studies in France, but he never entered on the duties of this office, Paris having become his second home. In 1826 he was charged by the French Government with the preparation of an edition of the *Sháh Námeh*, the first volume of which appeared in 1838, while the seventh and last was left unfinished at his death; in 1844 he was nominated to the Institut, and in 1847 he became professor of Persian at the Collége de France. But his knowledge and interest extended to all departments of Oriental learning, and this catholicity of taste, united to a singular impartiality of judgment and breadth of view, gave him a quite remarkable personal influence on the course of Eastern learning in France. The chief sphere of this influence was the Société Asiatique, which he served for many years as secretary-adjunct, as secretary, and finally as president. His annual reports on Oriental science, presented to the society from 1840 to 1867, and collected after his death (4th January 1876, at Paris) under the title *Vingt-sept Ans des Études Orientales* (Paris, 1879), are an admirable history of the progress of Eastern learning during these years, and justify the high esteem in which he was held by scholars.

MÖHLER, JOHANN ADAM (1796-1838), Roman Catholic theologian, was born at the village of Igersheim in Würtemberg on 6th May 1796, and, after studying philosophy and theology in the Lyceum at Ellwangen, entered the Wilhelmstift in the university of Tübingen in 1817. Ordained to the priesthood in 1819, he was appointed to a curacy at Riedlingen, but speedily returned as "repetent" to Tübingen, where he became privat-docent in 1822, extraordinary professor of theology in 1826, and ordinary in 1828. The controversies excited by his *Symbolik* (1832) proved so unpleasant that in 1835 he accepted a call to the university of Munich. In 1838 he was appointed to the deanery of Würzburg, but died shortly afterwards (12th April 1838).

Möhler wrote *Die Einheit in der Kirche* (Tübingen, 1825); *Athanasius der Grosse u. d. Kirche seiner Zeit im Kampfe m. d. Arianismus* (2 vols., Mainz, 1827); *Symbolik, oder Darstellung der dogmatischen Gegensätze der Katholiken u. Protestanten nach ihren öffentlichen Bekenntnissschriften* (Mainz, 1832; 8th ed., 1871-72; Eng. transl. by J. B. Robertson, 1843); and *Neue Untersuchungen der Lehrgegensätze zwischen den Katholiken u. Protestanten* (1834). His *Gesammelte Schriften u. Aufsätze* were edited by Dollinger in 1839; his *Patrologie* by Reithmayr, also in 1839; and a *Biographie* by Wörner was published at Ratisbon in 1866. It is with the *Symbolik* that his name is chiefly associated; the interest excited by it in Protestant circles is shown by the fact that within two years of its appearance it had elicited three replies of considerable importance, those namely of Baur, Marheineke, and Nitzsch. But, although characterized by abundant learning and acuteness, as well as by considerable breadth of spiritual sympathy, and thus a stimulative and suggestive work, it cannot be said to have been accepted by Catholics themselves as embodying an accurate objective view of the actual doctrine of their church. The liberal school of thought of which Mohler was a prominent exponent was discouraged in official circles, while Protestants, on the other hand, complain that the author has failed to grasp the vast significance of the Reformation as a great movement in the spiritual history of mankind, while expending needless pains on an exposition of the doctrinal shortcomings, inconsistencies, and contradictions of the individuals who were its leaders.

MOHR, KARL FRIEDRICH (1806-1879), a philosopher whose greatest claims to scientific distinction are as yet, though indubitable, only partially admitted, was the son of a well-to-do druggist in Coblentz, and was born 4th November 1806. Being a delicate child, he received much of his early education at home, in great part in his father's laboratory. To this may be traced much of the skill he showed in devising instruments and methods of analysis which are still in common use in chemical and pharmaceutical laboratories. At the age of 21 he studied chemistry under Gmelin, and, after five years spent in Heidelberg, Berlin, and Bonn, returned with the degree of Ph.D. to join his father's establishment. On the death of his father in 1840 he succeeded to the business, retiring from it for scientific leisure in 1857. Serious pecuniary losses led him at the age of 57 to become a privat-docent in Bonn, where he was soon after appointed, by the direct influence of the emperor, extraordinary professor of pharmacy. In private and domestic life he was a man of singularly winning manners, intensely fond of music and poetry, for the latter of which he showed wonderful memory. But his uncompromising spirit—perhaps we might even in some cases say his wrongheadedness—in matters of scientific and theological authority had raised such a host of enemies that even royal influence could not secure his further advancement. Although he stood at the very head of the scientific pharmacists of Germany, his name was deliberately omitted from the list of the commission entrusted with the preparation of the *Pharmacopœia Germanica*. Yet in that work many of his ideas and processes were incorporated by the very men who had previously denounced them. He died in October 1879.

Mohr's best-known work is his *Lehrbuch der chemisch-analytischen Titrirmethode* (1855), which has already run through many editions, and which was specially commended by Liebig. His improvements in methods of chemical analysis occupy a long series of papers extending over some fifty years. He also published a number of physical papers on subjects such as Hail, St. Elmo's Fire, Ground-ice, &c., and a curious notice of the earliest mention of Ozone. He shows that Homer, on four different occasions, mentions the sulphurous smell produced by lightning, and employs the very word from which the name of Ozone was long afterwards coined. In 1866 appeared his *Geschichte der Erde, eine Geologie auf neuer Grundlage*, which has obtained a wide circulation.

But he will be remembered in future times mainly on account of a paper, *Ueber die Natur der Warme*, published in 1837, which unfortunately has not yet appeared in full in an English translation. The history of this paper is remarkable. It was refused admission into *Poggendorff's Annalen*, and was then sent to Baumgartner of Vienna, in whose *Zeitschrift fur Physik*, &c., it was at once published. As no proof-sheets reached Mohr, he concluded that his paper had been lost or rejected, and contented himself with publishing a short analysis in the *Annalen der Pharmacie*, of which he was an editor. This analysis, it is only fair to say, though probably prepared by the author himself, gives a very inadequate idea of the scope and merit of the paper. In 1864 Dr. Akin unearthed the paper from the forgotten pages of the *Zeitschrift*, and the author was enabled to reprint it, with notes, while the recent discussions as to the history of Conservation of Energy were still being carried on. Along with it he issued a number of other papers of greatly inferior merit.

Unless some still earlier author should be discovered, there can be no doubt that Mohr is to be recognized as the first to enunciate in its generality what we now call "conservation of energy." The thesis of his paper must be stated in his own words,—"Besides the 54 known chemical elements, there is in the physical world one agent only, and this is called Kraft (energy).[1] It may appear, according to circumstances, as motion, chemical affinity, cohesion, electricity, light, and magnetism; and from any one of these forms it can be transformed into any of the others." Even now, after nearly half a century of rapid advance in science, it would be difficult to improve this statement except by inserting, as regards transformation of energy, some such guarding expression as "in whole or in part." But if Mohr had inserted this, he might have had claims to the "dissipation of energy" also. Mohr's starting-point appears to have been the discovery (by Forbes) of the polarization of radiant heat. He goes through the whole of the then range of physics, pointing out the explanation of each experimental result as a transformation of energy, mentioning even the electric currents produced by electro-magnetic induction as a transformation of the energy required to draw the coil from the magnet—one of the earlier methods used by Joule for quantitative determinations. His numerical results, based on data quoted from various books, are, it is

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composed of these distinct portions of matter separated, or capable of being separated, by empty space from other portions. But the *molecular* hypothesis of the constitution of different kinds of substances aims at analysing this process by which such substances are built up out of their constituent atoms. The *molecule* of any substance is, by some chemists, defined as being the smallest portion of that substance to which can be attributed all the chemical properties of the substance; by others, as the smallest portion which, so long as the substance is chemically unchanged, keeps together without complete separation of its parts. In the language of Clausius's theorem, if the parts of the molecule have internal motion, the kinetic energy of such internal motion is equal to the virial of the mutual attractive forces of the parts. Thus the formation of the molecule of each particular substance is viewed as an essential step in the process of building up that substance out of its constituent atoms. The molecule is first built up out of atoms arranged in its formation according to a definite type, and then the substance itself is constituted of these molecules. Of course molecules may be, and in fact in many particular substances are, supposed to be monatomic; that is to say, the intermediate step of building up the molecule out of the atoms has, in these particular substances, been omitted, the atoms and molecules becoming then identical. The particular arrangement of the formed molecules in the building up of the substance determines the physical state of that substance,—that is, its fluid, solid, gaseous, crystalline, or amorphous state; but the chemical properties of the substance depend upon the constitution of the molecule. As the investigations and theories of chemistry appear to indicate irresistibly the existence of permanent atoms, so do they also lead almost as necessarily to the conception of the molecule as an entity which bears the same relation to special substances that the atoms bear to matter generally. So long as the molecule endures, the substance of which it is the molecule retains its chemical properties; with the dissolution of the molecule, the substance, as that special substance, perishes; the atoms alone continue, and are free to enter into other combinations. The permanence of the molecule is relative, that of the atom absolute. This conception of the molecular constitution of substances suggests physical questions of great interest, such as the shape, volume, and mass of the constituent molecules, and the relative motions of which their parts are susceptible; and the answers to these questions cannot fail to be of great value in chemical and chemico-physical investigations, as well as in the theories of light and electricity.

Now, whatever differences may exist between the properties of different substances in the solid and liquid states, there are certain properties which, in the gaseous state, manifest themselves with no variation whatever in all substances alike. Hence the explanation of these common properties—or gaseous laws, as they are called—has long possessed a peculiar fascination for physicists. The tendency to expand or fill all accessible space, manifested by all gases, proves that on the molecular hypothesis their compound atoms or molecules must be continually tending to fly apart. We must conceive gases as constituted of molecules, not only separable but actually separated by space void of the matter of which these gases consist; and it may be most reasonably expected, therefore, that any general laws to which substances in this state conform may afford us a valuable insight into the constitution of these separate molecules.

Now the general laws to which all gases conform are: (1) *Boyle's law*—that, in a given mass of any gas kept at constant temperature, the pressure per unit of area upon the containing surface increases in the same proportion as the volume occupied by the gas is diminished, or at least with very slight deviation from exact proportionality; (2) *Charles's law*—that, if the temperature be varied while the pressure upon the gas remains the same, the gas increases by $\frac{1}{273}$d of its volume at zero centigrade for every degree of centigrade added to the temperature, or, which in combination with Boyle's law is the same thing, that if the density be constant, the pressure is directly proportional to the temperature measured from the point -273° centigrade, this point being called the zero of absolute temperature; (3) *Avogadro's law*—which asserts that all gases at the same temperature and pressure contain the same number of molecules in the same volume; and (4) *Dalton's law*—that in a mixture of different gases, when there is equilibrium, each gas behaves as a vacuum to all the rest.

It was at one time considered that these phenomena might be explained on the hypothesis of mutual repulsive forces between the parts of which the gas is composed, whether they were regarded as constituted of molecules or of infinitely divisible continuous matter,[1] but it has been shown in the article ATOM (vol. iii. p. 39 *sq.*) that there are at least two absolutely conclusive reasons why this explanation cannot be accepted. These objections, together with the experimental fact proved by Joule that gases, or at any rate atmospheric air, expand into vacuum with scarcely any appreciable change of temperature, must be considered fatal to any mutual-force theory of gaseous action, and, accordingly, physicists have been driven to seek for other methods of explaining these laws. The explanation which has been more developed than any other is that known as the kinetic theory of gases, which regards the intrinsic energy of a gaseous mass as residing, not in the potential energy of intermolecular forces, but mainly in the kinetic energy of the molecules themselves, which are assumed to be in a state of continual relative velocity, admitting at the same time a possible small intermolecular potential energy, and it may be also an interatomic energy, between the atoms of the individual molecules. That some such persistent relative motion does exist in every gaseous mass is evident from the rapidity with which odours penetrate the stillest air where no breath of wind—that is, of absolute motion of translation of the mass as a whole or any portion of finite size—is perceptible. It becomes an interesting question whether the laws of mechanics admit of a mass thus constituted ever arriving at a state of permanence; that is to say, whether, consistently with the hypothesis of infinite irregularities in the directions and magnitudes of velocities of individual molecules, there may be found any properties of the mass in the aggregate which remain

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x and $x+dx$, y and $y+dy$, z and $z+dz$, and component velocities intermediate between u and $u+du$, v and $v+dv$, w and $w+dw$, is

$$\psi(x, y, z, u, v, w)\, dx\, dy\, dz\, du\, dv\, dw.$$

In the state of permanence the form of ψ must be independent of the time (t), so long as the sphere is moving free from collisions with any other.

From the last-mentioned condition it must follow that, if $\phi_1=a_1$, $\phi_2=a_2$, &c., be any equations among the variables determining the position and motion of any sphere obtained by the elimination of t from the equations of motion of that sphere, then ψ must be of the form $\psi(\phi_1, \phi_2, \text{\&c.})$. With the assumption, then, that the number of spheres of the given set with variables between the above-mentioned limits is

$$\psi(\phi_1, \phi_2 \ldots)\, dx \ldots dw,$$

we find for the form of ψ, by reasoning like the foregoing, $Ae^{-h\left(\chi+\frac{mc^2}{2}\right)}$, where χ is the potential energy of the sphere in the position x, y, z, and $c^2=u^2+v^2+w^2$, and h is a constant, the same for all the sets.

If we integrate the expression $Ae^{-h\left(\chi+\frac{mc^2}{2}\right)}dx\, dy\, dz\, du\, dv\, dw$ for all values of x, y, z within the given region, we find for the number of spheres of any set with component velocities between u and $u+du$, v and $v+dv$, w and $w+dw$,

$$Be^{-\frac{hmc^2}{2}} du\, dv\, dw,$$

whence we easily see that the chances of velocities in all directions are the same, and that the mean velocity and mean square velocity of any sphere of this set are $\frac{2\sqrt{2\pi}}{\sqrt{mh}}$ and $\frac{3}{mh}$ respectively, and the mean kinetic energy of any such sphere is $\frac{3}{2h}$, and therefore the same for all the sets.

Furthermore, if we integrate the expression

$$Ae^{-h\left(\chi+\frac{mc^2}{2}\right)}dx\, dy\, dz\, du\, dv\, dw$$

for all values of u, v, and w from $-\infty$ to $+\infty$ respectively, we obtain a result of the form $Ce^{-h\chi}\, dx\, dy\, dz$, and therefore the number of spheres of the set in question with centres within the elementary volume $dx\, dy\, dz$, or, what is the same thing with the exception of a constant factor, the chance of the centre of any sphere of that set being within that elementary volume, is $Ce^{-h\chi}\, dx\, dy\, dz$, so that the *density of the N set of matter in the neighbourhood of the point* x, y, z is $mCe^{-h\chi}$.

We are now in a position to compare the physical properties of a medium composed of monatomic molecules in motion, and free from any intermolecular or interatomic forces with those of ordinary gases, so long at least as the atoms are spherical.

Consider two contiguous portions of such a medium separated by any plane parallel to that of yz, and, since the distribution and motion of each set of spheres is independent of all the other sets, let us confine our attention to the spheres of the N set. Suppose that there are N such spheres per unit volume in the neighbourhood of the point x, y, z, whose component velocities parallel to the axis of x are between u and $u+du$. The number of these spheres which cross the elementary area $dy\, dz$ in time dt will be the same as the number of the dN spheres whose centres are situated within the elementary parallelepiped $dx\, dy\, dz$, in which dx is equal to udt, and this number is

$$Nu\, dy\, dz\, dt.$$

Each of these spheres carries across with it a momentum parallel to x equal to mu; the total momentum parallel to x transferred across $dy\, dz$ in time dt is therefore

$$mNu^2\, dy\, dz\, dt.$$

If u be positive, this is positive momentum transferred from the negative to the positive side of the plane yz; and if u be negative, this is negative momentum similarly transferred from the positive to the negative side of that plane. In either case it follows that by the mere motion of these spheres across the area $dy\, dz$ the positive momentum parallel to the axis of x is diminished by the quantity $mNu^2\, dy\, dz\, dt$ on the negative side of the plane y z, and increased by the same quantity on the positive side of that plane in the time dt; m being, as before, the mass of each sphere. Hence, on the whole, there is a transference of positive x momentum in the time dt across the area $dy\, dz$ equal to $mdy\, dz\, dt\, \Sigma_{-\infty}^{\infty} u^2N$; that is, equal to

$$dy\, dz\, dt\, \rho\overline{u^2},$$

where ρ is the density of the N matter at the point x, y, z, and $\overline{u^2}$ is the mean square of the x velocities.

But either by integration or general reasoning it is easily seen that $\overline{u^2}=\frac{\overline{v^2}}{3}$, where $\overline{v^2}$ is the mean square of the resultant velocities of the N spheres, and is equal, as we have proved, to

$$\frac{3}{mh}.$$

Therefore, there is a transference of positive momentum from the negative to the positive side of the plane yz across the area $dy\, dz$ in time dt equal to

$$\frac{\rho\, dy\, dz\, dt}{mh}.$$

Each separate sphere whose component velocities are u, v, and w carries across the same area y and z momenta equal to mv and mw respectively, so that in the time dt there are carried across the area $dy\, dz\, y$ and z momenta equal to $\Sigma muv\, dy\, dz\, dt$ and $\Sigma muw\, dy\, dz\, dt$, respectively. By symmetry it is clear that Σmuv and Σmuw are separately zero. Therefore, the resultant mutual actions of the two portions of the medium under consideration in the time dt is the transference across the elementary area $dy\, dz$ of a quantity of x momentum equal to $\rho dy\, dz\, dt\, \frac{\overline{v^2}}{3}$ from the negative to the positive *side of the bounding plane. If this mutual action, or, as it is generally called,* "pressure" when referred to unit of surface, be denoted by the symbol p, we get the equation

$$p\, dy\, dz\, dt=\rho\, dy\, dz\, dt\frac{\overline{v^2}}{3},$$

or

$$p=\rho\,\frac{\overline{v^2}}{3}=\frac{\rho}{mh}.$$

Since the momenta parallel to y and z remain unaltered, it follows that the mutual action or pressure between contiguous portions of the medium in the neighbourhood of any point is normal to the bounding surface at that point. Since also the expression for p or $\frac{\rho}{mh}$ is independent of the direction of the x axis, it follows that the pressure at any point of the medium is the same in all directions.

If the contiguous portions of the medium be separated by a material instead of an ideal plane, it will be necessary for the maintenance of equilibrium that there should be an action between this plane and the adjacent medium, equivalent to the transference of momentum estimated above; but action measured by the rate per unit of time at which momentum is generated constitutes moving force or statical pressure. Hence the force or pressure between the plane and medium is normal to the plane, independent of the direction of the plane through the point, and equal to the value of $\frac{\rho}{mh}$ at the point.

When several sets of spheres are present together in the region under consideration, the distribution of the centres and of the velocities of each set is, as we have seen, independent of the coexistence of the other sets. If therefore ρ_1, ρ_2, &c., be the densities of the matter of the different sets in the neighbourhood of the point x, y, z, and if p_1, p_2, &c., be the pressures at that point defined as above, and if m_1, m_2, &c., be the masses of the spheres of each of the sets, and p the total pressure, we get

$$p=p_1+p_2+\text{\&c.}$$
$$=\frac{\rho_1}{m_1h}+\frac{\rho_2}{m_2h}+\text{\&c.}$$

Hence we arrive at the following conclusions:—(1) there is one physical quantity having the same value for every set of spheres—namely, the mean kinetic energy of each sphere, or $\frac{3}{2h}$; let this quantity be called τ; (2) the distribution of the positions and velocities of the spheres of each set is independent of the coexistence of the remaining sets, and is in all respects the same as if that particular set existed alone in the region considered; (3) the pressure at any point referred to unit of surface at any point of the medium arising from the action of any one of the sets is $\frac{2}{3m}\rho\tau$, where ρ is the density of that particular set at the point in question, and τ is the physical quantity above referred to as common to all the sets.

This third inference may be expanded into the following three laws:—(α) if τ be kept constant, then the pressure arising from each set varies as the density of that set; (β) if ρ be kept constant, then the pressure from each set varies as τ; (γ) if the pressures for all the sets be the same, then $\frac{\rho}{m}$ *is also the same, or the number* of spheres per unit volume is the same.

Now suppose there is a mixture of any number of gases in any region; when there is equilibrium there is one physical quantity, namely, temperature, which is the same for all; the intrinsic

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From the last-mentioned condition it must follow that, if $\phi_1=a_1$, $\phi_2=a_2$, &c., be any equations among the variables determining the position and motion of any sphere obtained by the elimination of t from the equations of motion of that sphere, then ψ must be of the form $\psi (\phi_1, \phi_2$, &c.). With the assumption, then, that the number of spheres of the given set with variables between the above-mentioned limits is

$$\psi (\phi_1, \phi_2 \ldots)\, dx \ldots dw,$$

we find for the form of ψ, by reasoning like the foregoing, $Ae^{-h\left(\chi+\frac{mc^2}{2}\right)}$, where χ is the potential energy of the sphere in the position x, y, z, and $c^2=u^2+v^2+w^2$, and h is a constant, the same for all the sets.

If we integrate the expression $Ae^{-h\left(\chi+\frac{mc^2}{2}\right)}dx\, dy\, dz\, du\, dv\, dw$ for all values of x, y, z within the given region, we find for the number of spheres of any set with component velocities between u and $u+du$, v and $v+dv$, w and $w+dw$,

$$Be^{-\frac{hmc^2}{2}}du\, dv\, dw,$$

whence we easily see that the chances of velocities in all directions are the same, and that the mean velocity and mean square velocity of any sphere of this set are $\frac{2\sqrt{2\pi}}{\sqrt{mh}}$ and $\frac{3}{mh}$ respectively, and the mean kinetic energy of any such sphere is $\frac{3}{2h}$, and therefore the same for all the sets.

Furthermore, if we integrate the expression

$$Ae^{-h\left(\chi+\frac{mc^2}{2}\right)}dx\, dy\, dz\, du\, dv\, dw$$

for all values of u, v, and w from $-\infty$ to $+\infty$ respectively, we obtain a result of the form $Ce^{-h\chi}\, dx\, dy\, dz$, and therefore the number of spheres of the set in question with centres within the elementary volume $dx\, dy\, dz$, or, what is the same thing with the exception of a constant factor, the chance of the centre of any sphere of that set being within that elementary volume, is $Ce^{-h\chi}\, dx\, dy\, dz$, so that the *density of the N set of matter in the neighbourhood of the point x, y, z is $mCe^{-h\chi}$.*

We are now in a position to compare the physical properties of a medium composed of monatomic molecules in motion, and free from any intermolecular or interatomic forces with those of ordinary gases, so long at least as the atoms are spherical.

Consider two contiguous portions of such a medium separated by any plane parallel to that of yz, and, since the distribution and motion of each set of spheres is independent of all the other sets, let us confine our attention to the spheres of the N set. Suppose that there are N such spheres per unit volume in the neighbourhood of the point x, y, z, whose component velocities parallel to the axis of x are between u and $u+du$. The number of these spheres which cross the elementary area $dy\, dz$ in time dt will be the same as the number of the dN spheres whose centres are situated within the elementary parallelepiped $dx\, dy\, dz$, in which dx is equal to udt, and this number is

$$Nu\, dy\, dz\, dt.$$

Each of these spheres carries across with it a momentum parallel to x equal to mu; the total momentum parallel to x transferred across $dy\, dz$ in time dt is therefore

$$mNu^2\, dy\, dz\, dt.$$

If u be positive, this is positive momentum transferred from the negative to the positive side of the plane $y\, z$; and if u be negative, this is negative momentum similarly transferred from the positive to the negative side of that plane. In either case it follows that by the mere motion of these spheres across the area $dy\, dz$ the positive momentum parallel to the axis of x is diminished by the quantity $mNu^2\, dy\, dz\, dt$ on the negative side of the plane $y\, z$, and increased by the same quantity on the positive side of that plane in the time dt; m being, as before, the mass of each sphere. Hence, on the whole, there is a transference of positive x momentum in the time dt across the area $dy\, dz$ equal to $mdy\, dz\, dt\, \Sigma_{-\infty}^{\infty} u^2N$; that is, equal to

$$dy\, dz\, dt\, \rho\overline{u^2},$$

where ρ is the density of the N matter at the point x, y, z, and $\overline{u^2}$ is the mean square of the x velocities.

But either by integration or general reasoning it is easily seen that $\overline{u^2}=\frac{\overline{v^2}}{3}$, where $\overline{v^2}$ is the mean square of the resultant velocities of the N spheres, and is equal, as we have proved, to

$$\frac{3}{mh}.$$

Therefore, there is a transference of positive momentum from the negative to the positive side of the plane $y\, z$ across the area $dy\, dz$ in time dt equal to

$$\frac{\rho\, dy\, dz\, dt}{mh}.$$

Each separate sphere whose component velocities are u, v, and w carries across the same area y and z momenta equal to mv and mw respectively, so that in the time dt there are carried across the area $dy\, dz\, y$ and z momenta equal to $\Sigma muv\, dy\, dz\, dt$ and $\Sigma muw\, dy\, dz\, dt$, respectively. By symmetry it is clear that Σmuv and Σmuw are separately zero. Therefore, the resultant mutual actions of the two portions of the medium under consideration in the time dt is the transference across the elementary area $dy\, dz$ of a quantity of x momentum equal to $\rho dy\, dz\, dt\, \frac{\overline{v^2}}{3}$ from the negative to the positive side of the bounding plane. If this mutual action, or, as it is generally called, "pressure" when referred to unit of surface, be denoted by *the symbol p, we get the equation*

$$p\, dy\, dz\, dt=\rho\, dy\, dz\, dt\frac{\overline{v^2}}{3},$$

or

$$p=\rho\,\frac{\overline{v^2}}{3}=\frac{\rho}{mh}.$$

Since the momenta parallel to y and z remain unaltered, it follows that the mutual action or pressure between contiguous portions of the medium in the neighbourhood of any point is normal to the bounding surface at that point. Since also the expression for p or $\frac{\rho}{mh}$ is independent of the direction of the x axis, it follows that the pressure at any point of the medium is the same in all directions.

If the contiguous portions of the medium be separated by a material instead of an ideal plane, it will be necessary for the maintenance of equilibrium that there should be an action between this plane and the adjacent medium, equivalent to the transference of momentum estimated above; but action measured by the rate per unit of time at which momentum is generated constitutes moving force or statical pressure. Hence the force or pressure between the plane and medium is normal to the plane, independent of the direction of the plane through the point, and equal to the value of $\frac{\rho}{mh}$ at the point.

When several sets of spheres are present together in the region under consideration, the distribution of the centres and of the velocities of each set is, as we have seen, independent of the coexistence of the other sets. If therefore ρ_1, ρ_2, &c., be the densities of the matter of the different sets in the neighbourhood of the point x, y, z, and if p_1, p_2, &c., be the pressures at that point defined as above, and if m_1, m_2, &c., be the masses of the spheres of each of the sets, and p the total pressure, we get

$$p = p_1 + p_2 + \text{\&c.}$$
$$= \frac{\rho_1}{m_1h} + \frac{\rho_2}{m_2h} + \text{\&c.}$$

Hence we arrive at the following conclusions:—(1) there is one physical quantity having the same value for every set of spheres—namely, the mean kinetic energy of each sphere, or $\frac{3}{2h}$; let this quantity be called τ; (2) the distribution of the positions and velocities of the spheres of each set is *independent of the coexistence* of the remaining sets, and is in all respects the same as if that particular set existed alone *in the region considered*; (3) the pressure at any point referred to unit of surface at any point of the medium arising from the action of any one of the sets is $\frac{2}{3m}\rho\tau$, where ρ is the density of that particular set at the point in question, and τ is the physical quantity above referred to as common to all the sets.

This third inference may be expanded into the following three laws:—(α) if τ be kept constant, then the pressure arising from each set varies as the density of that set; (β) if ρ be kept constant, then the pressure from each set varies as τ; (γ) if the pressures for all the sets be the same, then $\frac{\rho}{m}$ *is also the same, or the number of spheres per unit volume is the same.*

Now suppose there is a mixture of any number of gases in any *region*; when there is equilibrium there is one physical quantity, namely, temperature, which is the same for all; the intrinsic

Now to find this latter chance we observe that it is the chance of the s group being in their required limits of position and motion, when the internal forces between the r and s group become forces between the s group and fixed centres.

If the total kinetic energy of the r group in their given state be T_r, and that of the $r+s$ group be T_{r+s}, the total kinetic energy of the s group must be $T_{r+s} - T_r$.

Also if the total potential energy of the $r+s$ group under the influence of all forces be χ_{r+s}, this is made up of—

(1) χ_r, the potential energy of the r group to fixed centres, and of its internal forces;

(2) χ_s, similarly taken for the s group; and

(3) ${}_r\chi_s$, the potential energy of the r and s group forces.

And when the r group is fixed the potential energy of the s group is reduced to (2) and (3), or is $\chi_{r+s} - \chi_r$.

Therefore the chance of the s group having its variables within the required limits when the r group is fixed must be

$$\psi\,(E_{r+s} - E_r)\, dq_{r+1}\ldots dp_{r+s}$$

Therefore

$$\psi(E_r)\,\psi\,(E_{r+s} - E_r)\, dq_1\ldots dp_{r+s} = \psi\,(E_{r+s})\, dq_1\ldots dp_{r+s}$$

or

$$\psi\,(E_r)\,\psi\,(E_{r+s} - E_r) = \psi\,(E_{r+s}).$$

Therefore $\psi\,(x) = e^{Cx} = e^{-hx}$ suppose.

And the chances of the r group having its variables between the limits q_1 and $q_1 + dq_1\ldots p_r$ and $p_r + dp_r$ must, in the state of permanent or stable motion, be proportional to

$$e^{-hE_r}\, dq_1\ldots dp_r,$$

which was to be proved.

Supposing now that the aggregate of molecules under consideration consists of a number of sets of similar molecules, the number of molecules in one of these sets being N, where N is very large, and suppose that each of these N molecules possesses σ degrees of freedom defined by the coordinates $q_1\ldots q_\sigma$ with the momenta $p_1\ldots p_\sigma$, and that its mass is m. Three of these coordinates may be taken as the rectangular coordinates of its centre of mass, in which case the corresponding momenta will be mu, mv, mw, where u, v, and w are the component velocities of translation of that centre of mass. Then in this case, if $q_4\ldots q_\sigma$, $p_4\ldots p_\sigma$ be the remaining coordinates and momenta of the molecule, the chance of the molecule's variables being within the limits x and $x + dx\ldots p_\sigma$ and $p_\sigma + dp_\sigma$ will be proportional to

$$e^{-h(\chi + f)}\, dx\, dy\, dz\, dq_4\ldots dp_4\, e^{-h\frac{m}{2}(u^2+v^2+w^2)}\, du\, dv\, dw \ldots \text{(I)},$$

where T, the kinetic energy of the molecule, is equal to

$$\frac{m}{2}(u^2 + v^2 + w^2) + f,$$

where f is a quadratic function of the p's, having as coefficients known functions of the q's.

If we integrate the expression (I) for all possible values of x, y, z, $q_4\ldots q_\sigma$, $p_4\ldots p_\sigma$, we obtain an expression of the form

$$Be^{-h\frac{m}{2}c^2}\, du\, dv\, dw \ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(II)},$$

where B is independent of u, v, and w, and $c^2 = u^2 + v^2 + w^2$. From the form of (II) it follows, exactly as in the cases of the elastic spheres, that the chances of all directions of the velocity of translation of a molecule are equal, that the mean velocity and mean square velocity of translation of each molecule are

$$\frac{2^{\frac{3}{2}}\sqrt{\pi}}{\sqrt{mh}} \text{ and } \frac{3}{mh}$$

respectively, and that the mean kinetic energy of translation is $\frac{3}{2h}$, and the same for a molecule of any set.

Again, if $\overline{T}$ be the mean total kinetic energy of the molecule, then

$$\overline{T} = \frac{\iiint\ldots T.e^{-h(\chi+T)}\, dx\ldots dp_\sigma}{\iiint\ldots e^{-h(\chi+T)}\, dx\ldots dp_\sigma}\ \ldots\ldots\ldots\text{(III)};$$

and if we evaluate this expression, paying attention to the form of T as a quadratic function of the p's mentioned above, we shall find for (III) the expression $\frac{\sigma}{2h}$.

It follows from this result that each additional degree of freedom of the molecule increases the mean total kinetic energy of the molecule by the quantity $\frac{1}{2h}$, which is the mean kinetic energy of translation parallel to any one of the axes, and that the total kinetic energy is proportional to the number of such degrees of freedom.

If, again, we integrate the expression (I) for all values of the momenta, we obtain an expression of the form

$$Ce^{-h\chi}\, dx\, dy\, dz\, dq_4\ldots dq_\sigma \ldots\ldots\ldots\ldots\ldots\text{(IV)},$$

where χ is the potential energy of the molecule due to fixed centre and to interatomic forces in the position defined by x, y, z, $q_4\ldots q_\sigma$. The dimensions of the molecule are so small that we may regard forces from each fixed centre on different parts of the molecule as parallel and equal and functions of the distance of the centre of mass from that fixed centre, so that, if the part of χ arising from these fixed centre forces be called χ_1, χ_1 will be a function of x, y, z, and of these variables only, the remaining part of χ (arising from interatomic forces), which may be called χ_2, will be a function of the $\sigma - 3$ variables $q_4\ldots q_\sigma$.

If in (IV) we write $\chi_1 + \chi_2$ for χ, and then integrate for all values of $q_4\ldots q_\sigma$, we obtain an expression of the form

$$De^{-h\chi_1}\, dx\, dy\, dz \ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(V)},$$

where D is independent of x, y, z, and therefore ρ the density of the N molecule matter in the neighbourhood of the point x, y, z, is

$$mDe^{-h\chi_1}.$$

From these results all the propositions proved above with reference to the aggregate of elastic spheres or monatomic molecules, as to the correspondence of the physical properties of such an aggregate with those of gases as indicated by the gaseous laws, may be deduced also for this aggregate of polyatomic molecules. So that if $\overline{T}$ be equal to $\frac{3}{2h}$, or the mean kinetic energy of agitation of any one of the aggregate of moving molecules, if v be the volume occupied by unit of mass, r the number of molecules in unit of volume, and m the mass of each molecule, we have, exactly as in the case referred to,

$$mr = 1,\ \rho v = 1,$$

and

$$pv = \frac{2}{3}\, r\overline{T}.$$

We also get the ordinary hydrostatical equations

$$\frac{dp}{dx} = \rho X,\quad \frac{dp}{dy} = \rho Y,\quad \frac{dp}{dz} = \rho Z$$

from this expression for p combined with the equation

$$\rho = mDe^{-h\chi_1},$$

remembering that

$$\frac{d\chi_1}{dx} = -mX,\quad \frac{d\chi_1}{dy} = -mY,\quad \frac{d\chi_1}{dz} = -mZ,$$

whence the coincidence of the physical properties of this aggregate of polyatomic moving molecules with those of a gas, on the assumption that the temperature represents the mean kinetic energy of agitation, is at once apparent.

It can be shown also that the aggregate of moving molecules, such as we conceive a gas to be, possesses another very important physical property which, by its analogy to the second law of thermodynamics, affords additional evidence of the relation between the phenomena of heat and those of aggregates in some kind of motion,—the property in question being that, if in any aggregate of moving molecules the mean kinetic energy of any one of them be called τ, and if δQ be an increment of energy imparted to the aggregate from without, then $\frac{\delta Q}{\tau}$ is a perfect differential.

If to this aggregate we apply a certain small quantity δQ of heat or energy from without, and if $\delta\tau$ be the increase of the mean kinetic energy of agitation when the volume is unaltered, then this constancy of volume prevents any of the energy δQ from being absorbed in doing external work; but it is conceivable that the increase of τ may cause such a change in the average state of the molecule as to produce a variation $\delta\chi$ in the mean potential energy of the molecule, $\delta\chi$ being proportional to $\delta\tau$.

Therefore

$$\delta Q = r\left\{\frac{d\overline{T}}{d\tau} + \frac{d\chi}{d\tau}\right\}\delta\tau.$$

But

$$\overline{T} = \frac{\sigma}{2h} = \frac{\sigma}{3}\cdot\frac{3}{2h} = \frac{\sigma}{3}\tau;$$

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If the volume vary by δv, the pressure being constant, then we must add external work, or $p\delta v$, to the energy absorbed, so that if the whole external energy now applied be $\delta' Q$, and the increase of temperature $\delta\tau$ be the same in both cases, we have

$$\frac{\delta' Q}{\delta Q} = \frac{r\left(\frac{\sigma}{3} + \frac{d\chi}{d\tau}\right)\delta\tau + p\delta v}{r\left(\frac{\sigma}{3} + \frac{d\chi}{d\tau}\right)\delta\tau}.$$

But if p be constant, then as before

$$p\delta v = 2\,\frac{r}{3}\,\delta\tau,$$

Now to find this latter chance we observe that it is the chance of the s group being in their required limits of position and motion, when the internal forces between the r and s group become forces between the s group and fixed centres.

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$$Dc^{-h\chi_1}\,dx\,dy\,dz \ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(V)},$$

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Therefore

$$\delta Q = r\left\{\frac{d\overline{T}}{d\tau} + \frac{d\chi}{d\tau}\right\}\delta\tau.$$

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$$\frac{\delta' Q}{\delta Q} = \frac{r\left(\frac{\sigma}{3} + \frac{d\chi}{d\tau}\right)\delta\tau + p\delta v}{r\left(\frac{\sigma}{3} + \frac{d\chi}{d\tau}\right)\delta\tau}.$$

But if p be constant, then as before

$$p\delta v = 2\,\frac{r}{3}\,\delta\tau,$$

$$B=\frac{\omega}{l}\text{; or }\frac{1}{l}=\frac{B}{\omega}.$$

Hence the chance for such a molecule of free path between x and $x+dx$ is

$$\frac{B}{\omega}e^{-\frac{Bx}{\omega}}dx,$$

with the above definition of B.

The chance of a molecule whose velocity is ω having free path x is of course the same as the chance of its free path having the duration $\frac{x}{\omega}$. If $t=\frac{x}{\omega}$, the chance of duration between t and $t+dt$ is thus

$$\frac{B}{\omega}e^{-Bt}\,\omega dt\text{; or }Be^{-Bt}\,dt.$$

Meyer determines the value of B, if the molecules be spheres, in the form

$$B=N\pi s^2\Omega\left\{1+\frac{1}{1}\frac{1}{1.3}\omega^2h-\frac{1}{1.2}\cdot\frac{1}{3.5}\omega^4h^2+\right.$$

$$\left.(-)^{n-1}\frac{1}{\lfloor n}\,\frac{1}{2n-1}\cdot\frac{1}{2n+1}\,(\omega^2h)^n\ldots\right\},$$

where $\Omega=\frac{2}{\sqrt{\pi h}}$, and s is the sum of the radii of two molecules.

It will be observed that the series converges very rapidly if ω^2h is less than unity, the successive coefficients being

$$\frac{1}{3},\ -\frac{1}{30},\ +\frac{1}{210},\ -\frac{1}{1512},\ +\frac{1}{11880},\ \&c.$$

Having found B for the number of encounters experienced per unit of time by a molecule having velocity ω, we have for the average number of encounters experienced by any molecule per unit of time, which we denote by C,

$$C=\frac{4}{\sqrt{\pi}}h^{\frac{3}{2}}\int_0^\infty e^{-h\omega^2}\omega^2B\,d\omega.$$

From which Meyer deduces

$$C=2\frac{\sqrt{2\pi}}{h}\cdot Ns^2$$

$$=\Omega\sqrt{2}.N\pi s^2.$$

Hence the mean value of the free path for all molecules, irrespective of velocity, is $L=\frac{\Omega}{C}=\frac{1}{\pi\sqrt{2}Ns^2}$.

Thus the kinetic theory of gases presents to us the conception of apparently perfect rest, as the result of motion irregular in detail but permanent and stable on the average. Whatever difficulty may be felt at first sight in the acceptance of this theory in the case of a medium at rest is greatly enhanced when we pass to the contemplation of a disturbed medium like a mass of gas through which a wave of sound is passing. In our ordinary investigations of such a disturbance the gas is treated as a continuous body, subjected to small relative motions of its parts, accompanied by corresponding variations of internal pressure. When a disturbance or a local condensation or rarefaction is set up in any portion of this gas we calculate the resulting effects by the well-known equations of sound motion. But on this kinetic theory the medium is supposed to consist of a number of discrete masses—elastic spheres or the like—which preserve the physical properties of the medium merely by the recurrence of their mutual collisions, such collisions obeying no law in individual cases, but preserving a certain average uniformity in the motion of the whole aggregate; and we need some further investigation to assure ourselves of the applicability of the ordinary treatment of wave motion to such a medium.

Now we observe that the physical properties of our medium, so far as the relation between pressure, density, and temperature is concerned, merely require that the temperature be measured by the mean total kinetic energy of translation, and that the mean kinetic energy of translation parallel to any fixed line be equal to one-third of the mean total energy of translation. If the molecules constituting any portion of this medium were animated by a common velocity or acceleration, the physical properties of this portion would be similarly determined by the velocities and kinetic energies relative to the common motion. When the distribution of such relative velocities is stable or permanent, the average relative kinetic energy in any fixed direction is one-third of the average relative total kinetic energy, such property constituting normal distribution.

Suppose that in any portion of a medium, consisting of equal elastic spheres, this distribution has been disturbed—that is, Σmu^2, Σmv^2, and Σmw^2 are unequal. If V were the relative velocity of any pair of spheres after such disturbance and before they collide, and θ the angle between V and the common normal at the point of impact, then the normal and tangential relative velocities before impact are $V\cos\theta$ and $V\sin\theta$, and after impact they become $-V\cos\theta$ and $V\sin\theta$ respectively. The relative velocity after impact, resolved in the direction of relative velocity before impact, is therefore

$$-V\cos^2\theta+V\sin^2\theta,$$

or $-V\cos 2\theta$; and the chance of θ being between θ and $\theta+d\theta$ is

$$\sin 2\theta\,d\theta.$$

Therefore the average square relative velocity resolved in the original direction becomes after impact

$$\overline{V^2}\int_0^{\frac{\pi}{2}}\cos^2 2\theta\sin 2\theta\,d\theta\text{, or }\frac{\overline{V^2}}{3}.$$

The relative velocity after impact in the plane of V, and the normal perpendicular to the direction of V before impact is

$$V\sin\theta\cos\theta+V\sin\theta\cos\theta\text{, or }V\sin 2\theta.$$

And, if a fixed line be taken in the plane perpendicular to V, the average value of the square of the relative velocity after impact, resolved parallel to this line, is

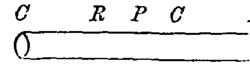
$$\frac{\overline{V^2}}{2\pi}\cdot\int_0^{2\pi}\int_0^{\frac{\pi}{2}}\sin^3 2\theta\cos^2\phi\,d\theta\,d\phi\text{, or }\frac{\overline{V^2}}{3}\text{ as before.}$$

Hence we conclude that, in whatever manner the distribution is disturbed in any portion of the medium at any instant, it will, for all those pairs of spheres which within any given interval encounter each other, have assumed the normal distribution after that interval.

If τ denote the average time between two collisions for any given sphere, the chance that this sphere shall continue for any time t free from collisions is, as we have seen, $c^{-\frac{t}{\tau}}$.

If, therefore, D be the number of spheres within any region whose total relative velocity is between w and $w+dw$, but so distributed that the mean square of their relative velocities along any fixed line is not $\frac{w^2}{3}$, then after a time t considerably greater than τ, say ten times τ, the number of the D spheres which have escaped collision will be utterly inconsiderable, and the distribution will have become normal throughout the region.

Suppose, for instance, that a sound wave is passing along a tube filled with air,



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The air in any section of the tube near P has alternately a small positive momentum and an equal small negative momentum, the reversal taking place in every $\frac{1}{500}$th of a second; also the same cause which produces the average momentum in either case disturbs the distribution of energy among the x, y, and z directions, *i.e.*, it is always producing an excess or defect in mu^2 above or below that of mv^2 and mw^2. By what has been proved above, this abnormal distribution of energy becomes inappreciable, owing to molecular collisions in a time considerably less than $\frac{1}{1000}$th of a second—in fact, in about $\frac{1}{500000000}$th of a second, when the value of T for atmospheric air is considered. It is therefore legitimate, in calculating the velocity of sound in air (at least on the elastic sphere hypothesis), to regard the distribution as always normal in any section of the tube, the air in that section or in any elementary portion of it possessing, as a whole, any given velocity or acceleration, estimated as if we were dealing with a continuous mass.

Diffusion of Gases.

If any further light is to be thrown on the physical nature of a molecule from investigations, experimental or analytical, concerning gases, it will most probably be by means of experiments on the diffusion of gases, or else on the internal friction or viscosity of gases, and the comparison of these results with those obtained analytically by the methods of the kinetic theory. Such investigations have been undertaken experimentally by Graham, Loschmidt, Maxwell, O. E. Meyer, and others. An account of them will be found in O. E. Meyer's work above referred to. The same problems have also been discussed analytically by Maxwell,[1] and by Stefan, O. E. Meyer, and Boltzmann in the treatises referred to below. We proceed to give a short account of Meyer's results.

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$$B=\frac{\omega}{l}\,;\ \text{or}\ \frac{1}{l}=\frac{B}{\omega}.$$

Hence the chance for such a molecule of free path between x and $x+dx$ is

$$\frac{B}{\omega}\,e^{-\frac{Bx}{\omega}}dx,$$

with the above definition of B.

The chance of a molecule whose velocity is ω having free path x is of course the same as the chance of its free path having the duration $\frac{x}{\omega}$. If $t=\frac{x}{\omega}$, the chance of duration between t and $t+dt$ is thus

$$\frac{B}{\omega}\,e^{-Bt}\,\omega dt\,;\ \text{or}\ Be^{-Bt}\,dt.$$

Meyer determines the value of B, if the molecules be spheres, in the form

$$B=N\pi s^2\Omega\left\{1+\frac{1}{1}\,\frac{1}{1.3}\,\omega^2h-\frac{1}{1.2}\cdot\frac{1}{3.5}\,\omega^4h^2+\right.$$

$$\left.(-)^{n-1}\,\frac{1}{\lfloor n}\,\frac{1}{2n-1}\cdot\frac{1}{2n+1}\,(\omega^2h)^n\ldots\right\},$$

where $\Omega=\frac{2}{\sqrt{\pi h}}$, and s is the sum of the radii of two molecules.

It will be observed that the series converges very rapidly if ω^2h is less than unity, the successive coefficients being

$$\frac{1}{3},\ -\frac{1}{30},\ +\frac{1}{210},\ -\frac{1}{1512},\ +\frac{1}{11880},\ \text{\&c.}$$

Having found B for the number of encounters experienced per unit of time by a molecule having velocity ω, we have for the average number of encounters experienced by any molecule per unit of time, which we denote by C,

$$C=\frac{4}{\sqrt{\pi}}\,h^{\frac{3}{2}}\int_0^\infty e^{-h\omega^2}\omega^2B\,d\omega.$$

From which Meyer deduces

$$C=2\,\frac{\sqrt{2\pi}}{h}\,.\,Ns^2$$
$$=\Omega\sqrt{2}\,.\,N\pi s^2.$$

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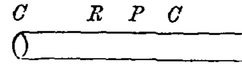

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Hence, if we attempt to cause one stratum of gas to pass over another in parallel planes, we experience a resistance due to the interchange of molecules between the portions of gas separated by the plane. This is in some respects analogous to sliding friction between solid bodies, and is called by German writers the "friction" (*Reibung*), by Maxwell and others the "viscosity," of the gas. Meyer[1] investigates this effect of friction in a manner somewhat similar to that employed in case of diffusion, and obtains for the coefficient of viscosity $\frac{1}{3}\, mN\overline{\omega l}$.

Relation of the Coefficient of Viscosity to Density and Temperature.—The viscosity of a gas is independent of the density, being, according to O. E. Meyer, $\frac{mN}{3}\overline{\omega l}$. Now, for any one gas, l_ω is, as we have seen, inversely proportional to the density, and therefore $\overline{\omega l}$ is inversely proportional to the density. On the other hand, N is directly proportional to the density. Hence the viscosity is independent of the density. This agrees with the result obtained by Maxwell from the kinetic theory in 1860, and with the results of experiments by Maxwell[2] and O. E. Meyer.[3] Also, experiments by O. E. Meyer and Springmühl[4] on the *transpiration* of gases show that the times in which two different gases under similar circumstances flow through a tube maintain the same constant ratio to one another. As in the case of the coefficient of diffusion, $\overline{\omega l}$ is inversely proportional to the square root of the absolute temperature. As both the coefficient of diffusion and that of viscosity depend on the same function $\overline{\omega l}$, it should be possible from experiments on viscosity to determine the rate of diffusion. Experiments with this object have been conducted by Stefan[5] with very satisfactory results, his calculated values for the coefficient of diffusion agreeing very closely with those determined by Loschmidt's direct experiment.[6]

We have given the above results for the coefficients of diffusion and viscosity from O. E. Meyer's work, because his method has met with very general acceptance. It has been shown, however, by Boltzmann,[7] that the method is incomplete. Meyer's results can only be obtained on the assumption that the molecules of a gas undergoing diffusion or internal friction, which have any given velocity, as w, *are moving with that velocity in all directions indifferently*. We may calculate the number of molecules having velocity w that pass through a given plane during a short time dt, starting from encounters at any given distance from the plane. If we assume that the molecules, issuing from such encounters with velocity w, move indifferently in all directions, we obtain Meyer's result. This assumption is true only of a gas at rest—that is, having no velocity of translation—so that our result so obtained would express, in case of diffusion, *the rate at which two gases begin to diffuse, if* given at any instant both at rest—that is, with no stream velocity—but mixed in unequal proportions in different parts of space. In any actual case of diffusion, either of the two diffusing gases acquires a small velocity of translation. If we take this velocity into account in calculating the number of molecules of the gas passing through a plane, according to Meyer's method, we shall find that it introduces two new terms, one of which, when the motion becomes steady, is equal and opposite to the result obtained by Meyer. This is proved by Boltzmann in the case of viscosity in the treatise above referred to. The same proof is easily applied in the case of diffusion.

Stefan's Method.—Stefan[8] regards the two diffusing gases as having small velocities of translation, or stream velocities, u_1 and u_2, in opposite directions, so that the molecules of one gas, of mass m_1, have an average momentum m_1u_1 in direction from left to right, and those of the other gas, of mass m_2, an average momentum m_2u_2 from right to left. By virtue of encounters between the two sets of molecules, each gas is always imparting to the other a portion of its own average momentum, and receiving from the other a corresponding momentum in the opposite direction. The momentum so transferred or interchanged is what Stefan calls the *resistance* which one gas offers to the other's diffusion. In this investigation Stefan assumes that all classes of molecules of one gas, whatever their molecular velocity in space, have the same average velocity in the direction of diffusion—that is, the same stream velocity—so that the motion of the molecules of a diffusing gas would be exactly represented by considering the molecules of a gas at rest—that is, with only its molecular velocity—at the same temperature and pressure, and then giving to each molecule the additional common velocity u in the direction of diffusion. Boltzmann, however, shows that, in order correctly to represent the motion of the diffusing gas, we must impart to molecules having different molecular velocities independent of direction different common velocities in the direction of diffusion. And it will be found that the resistance of the gases is sensibly modified by this property.[9]

The complete solution of the problem,—that is, the determination of u as a function of w, on the hypothesis that the molecules are elastic spheres,—is difficult.

If we assume molecules to be centres of force varying inversely as the nth power of the distance, so that the force at distance r is $\frac{\mu}{r^n}$, where μ is constant, we obtain the following result. We assume the molecules of gas A whose absolute velocities are between w and $w+dw$ to have an average stream velocity u in direction of the tube, where u is a function of w. Then, if the terminal condition at the ends of the tube *be maintained constant*, we obtain an equation of the form

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multiplied by the average value for all molecules of gas A of $u\,V^{\frac{n-5}{n-1}}$, where V is the relative velocity of two molecules, one taken from each gas, and C is a constant, and m_1, m_2 the masses of the molecules of gas A and gas B respectively.

By making n infinite we obtain the result for elastic spheres: in that case $V^{\frac{n-5}{n-1}}=V$, and the problem is to find the average value of uV.

Since p varies as the absolute temperature, and the average value of V varies as the square root of the absolute temperature, we may infer that the average value of u—that is, the stream velocity—will vary approximately as the square root of the temperature, as it appears to do from experimental evidence. If, on the other hand, $n=5$, V disappears, and $\frac{4n-8}{3n-3}=1$. In this case the analytical determination of u presents no difficulty; but in the result the stream velocity varies as the absolute temperature, which accords less satisfactorily with experiments.

On Molecular Dimensions.

Many attempts have been made in recent years to form an estimate or conjecture, more or less accurate, of the numerical value of the dimensions of a molecule and the absolute force between molecules.[10]

In accordance with the view of the subject considered in this article, we are here concerned with such speculations only in so far as they are founded upon the kinetic theory of gases, or supported by it. The phenomena of diffusion and viscosity especially have afforded grounds for estimates of molecular dimensions.

It is first necessary to define what is meant by the dimensions of a molecule. Regarded as an elastic sphere, it has dimensions with the conception of which we are familiar. It is not, of course, seriously contended by any physicists that the molecules of a gas are actually hard elastic spheres, exerting no force on each other at any distance greater than that of actual contact, and then an infinite force. It is necessary to conceive the forces as finite, although they may diminish so rapidly with the distance as that the motions of molecules in the aggregate differ little from what they would be if the molecules were ideal elastic spheres. Nevertheless, they must be finite forces; and, that being the case, it is difficult, if not impossible, to frame a definition of the boundary of a molecule, except as a certain surface at which the forces acting between the molecule in question and other molecules attain a certain value.

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5 *Sitzungsber. d. k.-k. Akad.*, 1872, lxv. 323.

6 For a full account of these and other experiments on diffusion and viscosity, see O. E. Meyer, *Kinetische Theorie d. Gase*, under the heads "Reibung" and "Diffusion."

7 "Zur Gas-Reibung," in the *Sitzungsber. d. k.-k. Akad.*, 1881.

8 Memoir "On the Dynamical Theory of Diffusion" (*Sitzungsber. d. k.-k. Akad.*, lxv.)

9 For Boltzmann's own treatment of the subject we cannot, within the limits of this article, do more than refer the reader to the memoir above mentioned, "Zur Gas-Reibung," and another as yet unfinished memoir "On Diffusion," in the *Sitzungsber. d. k.-k. Akad.*, 1882.

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1 See pp. 311-325 of the work above referred to.
2 *Proceedings of the Royal Society*, 8th February 1866.
3 *Poggendorff's Annalen*, 1871, cxliii. 14.
4 *Pogg. Ann.*, 1873, cxlviii. 1 and 526.
5 *Sitzungsber. d. k.-k. Akad.*, 1872, lxv. 323.
6 For a full account of these and other experiments on diffusion and viscosity, see O. E. Meyer, *Kinetische Theorie d. Gase*, under the heads "Reibung" and "Diffusion."
7 "Zur Gas-Reibung," in the *Sitzungsber. d. k.-k. Akad.*, 1881.
8 Memoir "On the Dynamical Theory of Diffusion" (*Sitzungsber. d. k.-k. Akad.*, lxv.)

9 For Boltzmann's own treatment of the subject we cannot, within the limits of this article, do more than refer the reader to the memoir above mentioned, "Zur Gas-Reibung," and another as yet unfinished memoir "On Diffusion," in the *Sitzungsber. d. k.-k. Akad.*, 1882.
10 An account of these will be found in O. E. Meyer's *Kin. Theorie d. Gase*, in Professor Tait's *Recent Advances in Physical Science*, lect. xii., and in the following memoirs:—*Phil. Mag.*, July 1879, "On the Size of Molecules," by N. D. C. Hodges; *Phil. Mag.*, March 1880, "On the Mean Free Path of Molecules," by the same author. See also, lecture delivered by Sir W. Thomson at the Royal Institution, 2d Feb. 1883.

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But, while for practical purposes these proportional numbers are quite sufficient, we cannot leave out of view their relation to the actual constitution of matter. There is good reason to believe that matter consists of discrete particles, and that every pure substance is made up of small portions of matter, all alike, so that one of them, if we could examine it, would give us a complete idea of the chemical composition, constitution, and character of the substance. These small portions, of which the smallest quantity of the substance which we can examine contains many millions, we may call *molecules*. From the character which we have supposed this molecule to possess—viz., that it fully represents all the chemical properties of the substance—it will be seen that these *real, ultimate* molecules must be proportional to the molecular weights ascertained by chemical means; so that, while for practical laboratory or manufacturing purposes we use the gramme, the pound, or the ton as our unit, and speak of 18 grammes, pounds, or tons, as the case may be, of water, as a molecule (or gramme-molecule, ton-molecule, &c.), in dealing with the actual constitution of matter we should use as our unit the mass of a single atom of hydrogen, and our gramme-molecule would then be a definite, very large, but not yet accurately ascertained, number of real molecules.

It has been already shown above that, on the kinetic theory of gas, a gas consists of a number of particles moving about in straight lines in all directions, and that in a homogeneous gas which follows Boyle's and Charles's laws these particles are all alike. The masses of the particles of different gases are therefore to one another in the same proportion as the densities of the gases, temperature and pressure being the same. Thus, in gases, the independently moving particles of the kinetic theory are the molecules of which the chemist is in search, and it becomes important that we should compare our chemically found molecular weights with the densities. Theoretically accurate results could be obtained only in the case of a perfect gas; but small deviations from Boyle's and Charles's laws do not interfere with the application of this method. Chemical methods, as we have already seen, lead us to a particular number, *or a multiple of it*, so that our choice is as a rule limited to two or three numbers widely differing from one another. We find that if we do not exceed the limits of chemical stability a gas approaches the state of a perfect gas as the temperature increases, or as the pressure diminishes. Now if one of the numbers rendered probable by chemical evidence *nearly* coincides with that given by comparison of gas densities, under conditions where the substance sensibly deviates from Boyle's and Charles's laws, we find that by diminishing the pressure or increasing the temperature within the limits of chemical stability, and thus bringing the substance nearer the state of a perfect gas, the correspondence between these two numbers becomes closer. This has already been pointed out and illustrated in the article CHEMISTRY, vol. v. p. 469.

We can now compare the results, in the case of gases, of the chemical and of the physical determination of molecular weight, by giving some examples, placing side by side the formula and molecular weight adopted by chemists, and the mass, in grammes, of the gas occupying the volume of $22{\cdot}33 \times 760/p \times (273+t)/273$ litres. This volume is that which one gramme of an ideal gas having the molecular weight 1, and perfectly following Boyle's and Charles's laws, would occupy at pressure p millimetres of mercury and temperature $t°$ C. If, then, w be the molecular weight of any gas, w grammes of it should occupy this volume, and slight deviation from this would indicate slight deviation from Boyle's and Charles's laws. In the annexed table w is the molecular weight and m the mass contained in $22{\cdot}33 \times 760/p \times (273+t)/273$ litres. Where the temperature is not specially stated, the determinations were made under the usual atmospheric conditions.

Name.	Formula.	w.	m.	
Sulphuretted hydrogen ...	H_2S	34	34·04	
Nitrous oxide ...	N_2O	44	44·08	
Ammonia ...	NH_3	17	17·12	
Carbonic acid ...	CO_2	44	44·14	
Marsh gas ...	CH_4	16	16·13	
Olefiant gas ...	C_2H_4	28	28·44	
Hydrogen ...	H_2	2	2	
Oxygen ...	O_2	32	32	
Chlorine ...	Cl_2	71	71·27	at 100° C.
Phosphorus ...	P_4	124	125·2	" 500° C.
Arsenic ...	As_4	300	294·5	" 860° C.
Sulphur ...	S_6	192	194	" 500° C.
	S_2	64	63·5	" 1000° C.
Bromide of aluminium ...	Al_2Br_6	534	537·5	" 440° C.
Ferric chloride ...	Fe_2Cl_6	325	328·8	" 440° C.
Sal-ammoniac ...	NH_4Cl	53·5	29·6	at 350° C.
Oil of vitriol ...	H_2SO_4	98	50·24	" 440° C.
Pentachloride of phosphorus ...	PCl_5	208·5	140	" 200° C.
			105·4	" 300° C.
Sulphide of ammonium ...	$(NH_4)_2S$	68	22·76	" 80° C.

A comparison of the values of w and m leads to the following conclusions:—

(1) In the case of a very great number of substances, of which only a few specimens are given in the table, the two determinations agree, the slight differences often observed being evidently due to deviation of the substance from the state of a perfect gas. (2) In a considerable number of substances, physical evidence leads to a multiple of the simplest number satisfying the chemical conditions. This cannot be looked upon as a disagreement between the methods, because, if a particular formula satisfies the chemical conditions, any multiple of it will necessarily do so; and indeed, in many of the cases we are now considering, it is possible from chemical considerations to justify the higher molecular weight after it has been suggested, although such chemical considerations might not in all cases have warranted its adoption without external support. Thus, we are not without chemical evidence in

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MOLINE, a city of the United States, in Rock Island county, Illinois, is situated in a picturesque district on the left bank of the Mississippi, opposite the upper end of Rock Island. First settled in 1832, the town was organized as a city in 1872. It is noted for its water-power, developed and maintained by the Government, and for the number and importance of its manufacturing establishments. By means of a dam nearly a mile in length, from the Illinois shore to the island, an almost uniform head of 7 feet of water is obtained, which is used in driving the machinery of the Government arsenal on the island, and in supplying power to several factories. Beds of bituminous coal are mined in the neighbourhood, and three lines of railway pass through the city, affording with the river ample means of communication. The most prominent manufactures are agricultural implements and machinery generally, waggons, organs, paper, and stoves. Moline has nine churches, a complete system of graded free schools, including a high school, and a free library. The population increased from 4066 in 1870 to 7805 in 1880, and with the suburbs the number is now estimated at 12,000.

MOLINOS, MIGUEL DE (1627-c. 1696), a Spanish priest whose name is intimately associated with that type of religion known in Italy and Spain during the latter half of the 17th century as Quietism, was born of good family in the diocese of Saragossa, on 21st December 1627. Having entered the priesthood, he settled about his fortieth year in Rome, where he speedily rose to high repute as a father confessor, and gained many distinguished friends, among whom were several cardinals, including Odescalchi (afterwards Innocent XI., 1676). In 1675 he published at Rome a small duodecimo volume entitled *Guida spirituale che disinvolge l'anima e la conduce per l'interior camino all' acquisto della perfetta contemplazione e del ricco tesoro della pace interiore*, which was soon afterwards followed by the *Breve trattato della cottidiana communione*, usually bound up with it in later editions. The work, which breathes a spirit of simple and earnest piety, is designed to show how inward peace may be found by what may be called contemplative or passive prayer, by obedience, by frequent communion, and by inward mortification; it was widely circulated, and greatly increased the popularity of its author, whom Innocent XI. after his elevation provided with rooms in the Vatican, and is said to have also taken as his spiritual director. Its doctrine of the passivity of the highest contemplation and purest prayer does not appear to have raised the slightest discussion until after the publication, in 1681, of the *Concordia tra la fatica e la quiete nell' oratione*, by the Jesuit preacher, Paolo Segneri. Although scrupulously refraining from any mention of the name of Molinos, and indeed displaying considerable moderation as a controversialist, Segneri by this tract and by another with which he followed it up brought upon himself much unpopularity; and so great did the excitement become that a committee was at last appointed by the Inquisition to investigate his own views as well as to examine the writings of Molinos and of his friend Petrucci (author of *La contemplazione mistica acquistata*). The report (1682) was entirely favourable to the doctrines of the *Guida Spirituale*, the writings of Segneri being censured as scandalous and heretical; but in 1685, in consequence of representations made to the pope by Louis XIV., under the Jesuit influence of Père La Chaise, both Petrucci and Molinos were laid under arrest, and the papers of the latter, including a voluminous correspondence, seized. Petrucci was soon afterwards liberated, and relieved from further persecution by the gift of a cardinal's hat; but, after Molinos had languished in confinement for two years, suddenly 200 persons, many of them of high rank, were also apprehended by order of the Inquisition for what were then for the first time called "Quietist" opinions. In 1687 the pope signified his approval of the condemnation pronounced by the Inquisition on sixty-eight doctrines imputed to Molinos. The "heretic" forthwith "abjured" these, and thus escaped the flames indeed, but did not regain his liberty. Of his later years nothing is known; according to the most probable accounts he languished in imprisonment until 28th December 1696.

The evidence on which certain charges of immorality against Molinos were based is unknown, and the degree of his responsibility for certain of the condemned propositions is obscure; but a perusal of the *Guida Spirituale* at least does not disclose to the candid reader any reason wherefore Molinos should not have been tolerated within a church which has canonized St Theresa. The explanation of the treatment to which he was subjected is most probably to be sought rather in the negative than in the positive aspects of his teaching, and still more in the passing exigencies of party politics. As Tholuck remarks, it was hardly to be expected that the Society of Jesus should regard as otherwise than highly dangerous a man who "declared confession and *outward* mortification to be work only for beginners, who himself abstained from confessing for twelve years on end, by whose advice countless monks and nuns had thrown aside chaplets, images, and reliques, that they might worship God in the spirit, and who, moreover, stood well with the fashionable world and with the pope himself." The *Guida Spirituale* was published in Spanish at Madrid in 1676, and frequently afterwards; it was also translated into Latin (*Manuductio Spiritualis*, Leipsic, 1687) by A. H. Francke, the well-known German pietist and philanthropist, and an English version (*The spiritual guide, which disentangles the soul and brings it by the inward way to the getting of perfect contemplation and the rich treasure of eternal peace: with a brief treatise concerning daily communion*) appeared in 1688. The materials for a history of the Quietist controversy are very fully given in the third volume of Gottfried Arnold's *Kirchen-und Ketzerhistorie*. See also Heppe, *Geschichte der quietistischen Mystik in der Katholischen Kirche* (Berlin, 1875); Tholuck's article on "Molinos" in Herzog's *Realencyklopädie*; and Bigelow, *Molinos the Quietist*, New York, 1882.

MOLISE, now CAMPOBASSO, a province of Italy, stretching twenty miles along the coast of the Adriatic, and bounded by the Abruzzi (Chieti and Aquila), Terra di Lavoro (Caserta), Benevento, and Capitanata (Foggia). Most of it lies on the north-eastern side of the Apennines, and is watered by the Biferno, the Forlone, and the Trigno; but it also includes the country on the other side which contains the head streams of the Volturno. About five-sixths of the surface may be described as mountainous or hilly, the loftiest range being the Matese on the borders towards Benevento, with its highest point in Monte Miletto, 6750 feet. The population, which increased from 346,007 in 1861 to 365,434 in 1881, is mainly dependent on pastoral and agricultural pursuits, neither manufactures nor trade being highly developed. According to the census of 1871, there were six places with more than 5000 inhabitants—Campobasso, 12,890; Riccia, 8123; Isernia, 7715; Agnone, 7147; Cascalende, 6217; and Larino, 5357; according to the census of 1881, 21 of the 133 communes had a population exceeding 4000.

The Molise territory was in ancient times part of the country of the Sabines and Samnites. Under the Lombards it was included in the duchy of Benevento; but the districts of Sepino, Boiano, and Isernia were cut off to form a domain for the Bulgarians who had come to assist King Grimoald. About two centuries later this became the countship of Boiano, and the name was soon after changed to countship of Molise, probably because the lordship was held by Ugone di Molisio, or Molise. Attached under Frederick II. to the Terra di Lavoro, and at a later date incorporated with Capitanata, the district did not again become an independent province till 1811. In 1861 it surrendered fifteen communes to Benevento, and received thirteen from Terra di Lavoro.

with prohibiting all further discussion of the question "de auxiliis," and studious efforts were made to control the publication even of commentaries on Aquinas. The Molinist subsequently passed into the Jansenist controversy, and it is as a champion of Jansenism that Pascal in the *Provincial Letters* attacks Molina and the *scientia media* (see JANSENISM).

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MOLINOS, MIGUEL DE (1627-c. 1696), a Spanish priest whose name is intimately associated with that type of religion known in Italy and Spain during the latter half of the 17th century as Quietism, was born of good family in the diocese of Saragossa, on 21st December 1627. Having entered the priesthood, he settled about his fortieth year in Rome, where he speedily rose to high repute as a father confessor, and gained many distinguished friends, among whom were several cardinals, including Odescalchi (afterwards Innocent XI., 1676). In 1675 he published at Rome a small duodecimo volume entitled *Guida spirituale che disinvolge l'anima e la conduce per l'interior camino all' acquisto della perfetta contemplazione e del ricco tesoro della pace interiore*, which was soon afterwards followed by the *Breve trattato della cottidiana communione*, usually bound up with it in later editions. The work, which breathes a spirit of simple and earnest piety, is designed to show how inward peace may be found by what may be called contemplative or passive prayer, by obedience, by frequent communion, and by inward mortification; it was widely circulated, and greatly increased the popularity of its author, whom Innocent XI. after his elevation provided with rooms in the Vatican, and is said to have also taken as his spiritual director. Its doctrine of the passivity of the highest contemplation and purest prayer does not appear to have raised the slightest discussion until after the publication, in 1681, of the *Concordia tra la fatica e la quiete nell' oratione*, by the Jesuit preacher, Paolo Segneri. Although scrupulously refraining from any mention of the name of Molinos, and indeed displaying considerable moderation as a controversialist, Segneri by this tract and by another with which he followed it up brought upon himself much unpopularity; and so great did the excitement become that a committee was at last appointed by the Inquisition to investigate his own views as well as to examine the writings of Molinos and of his friend Petrucci (author of *La contemplazione mistica acquistata*). The report (1682) was entirely favourable to the doctrines of the *Guida Spirituale*, the writings of Segneri being censured as scandalous and heretical; but in 1685, in consequence of representations made to the pope by Louis XIV., under the Jesuit influence of Père La Chaise, both Petrucci and Molinos were laid under arrest, and the papers of the latter, including a voluminous correspondence, seized. Petrucci was soon afterwards liberated, and relieved from further persecution by the gift of a cardinal's hat; but, after Molinos had languished in confinement for two years, suddenly 200 persons, many of them of high rank, were also apprehended by order of the Inquisition for what were then for the first time called "Quietist" opinions. In 1687 the pope signified his approval of the condemnation pronounced by the Inquisition on sixty-eight doctrines imputed to Molinos. The "heretic" forthwith "abjured" these, and thus escaped the flames indeed, but did not regain his liberty. Of his later years nothing is known; according to the most probable accounts he languished in imprisonment until 28th December 1696.

The evidence on which certain charges of immorality against Molinos were based is unknown, and the degree of his responsibility for certain of the condemned propositions is obscure; but a perusal of the *Guida Spirituale* at least does not disclose to the candid reader any reason wherefore Molinos should not have been tolerated within a church which has canonized St Theresa. The explanation of the treatment to which he was subjected is most probably to be sought rather in the negative than in the positive aspects of his teaching, and still more in the passing exigencies of party politics. As Tholuck remarks, it was hardly to be expected that the Society of Jesus should regard as otherwise than highly dangerous a man who "declared confession and *outward* mortification to be work only for beginners, who himself abstained from confessing for twelve years on end, by whose advice countless monks and nuns had thrown aside chaplets, images, and reliques, that they might worship God in the spirit, and who, moreover, stood well with the fashionable world and with the pope himself." The *Guida Spirituale* was published in Spanish at Madrid in 1676, and frequently afterwards; it was also translated into Latin (*Manuductio Spiritualis*, Leipsic, 1687) by A. H. Francke, the well-known German pietist and philanthropist, and an English version (*The spiritual guide, which disentangles the soul and brings it by the inward way to the getting of perfect contemplation and the rich treasure of eternal peace: with a brief treatise concerning daily communion*) appeared in 1688. The materials for a history of the Quietist controversy are very fully given in the third volume of Gottfried Arnold's *Kirchen-und Ketzerhistorie*. See also Heppe, *Geschichte der quietistischen Mystik in der Katholischen Kirche* (Berlin, 1875); Tholuck's article on "Molinos" in Herzog's *Realencyklopädie*; and Bigelow, *Molinos the Quietist*, New York, 1882.

MOLISE, now CAMPOBASSO, a province of Italy, stretching twenty miles along the coast of the Adriatic, and bounded by the Abruzzi (Chieti and Aquila), Terra di Lavoro (Caserta), Benevento, and Capitanata (Foggia). Most of it lies on the north-eastern side of the Apennines, and is watered by the Biferno, the Forlone, and the Trigno; but it also includes the country on the other side which contains the head streams of the Volturno. About five-sixths of the surface may be described as mountainous or hilly, the loftiest range being the Matese on the borders towards Benevento, with its highest point in Monte Miletto, 6750 feet. The population, which increased from 346,007 in 1861 to 365,434 in 1881, is mainly dependent on pastoral and agricultural pursuits, neither manufactures nor trade being highly developed. According to the census of 1871, there were six places with more than 5000 inhabitants—Campobasso, 12,890; Riccia, 8123; Isernia, 7715; Agnone, 7147; Cascalende, 6217; and Larino, 5357; according to the census of 1881, 21 of the 133 communes had a population exceeding 4000.

The Molise territory was in ancient times part of the country of the Sabines and Samnites. Under the Lombards it was included in the duchy of Benevento; but the districts of Sepino, Boiano, and Isernia were cut off to form a domain for the Bulgarians who had come to assist King Grimoald. About two centuries later this became the countship of Boiano, and the name was soon after changed to countship of Molise, probably because the lordship was held by Ugone di Molisio, or Molise. Attached under Frederick II. to the Terra di Lavoro, and at a later date incorporated with Capitanata, the district did not again become an independent province till 1811. In 1861 it surrendered fifteen communes to Benevento, and received thirteen from Terra di Lavoro.

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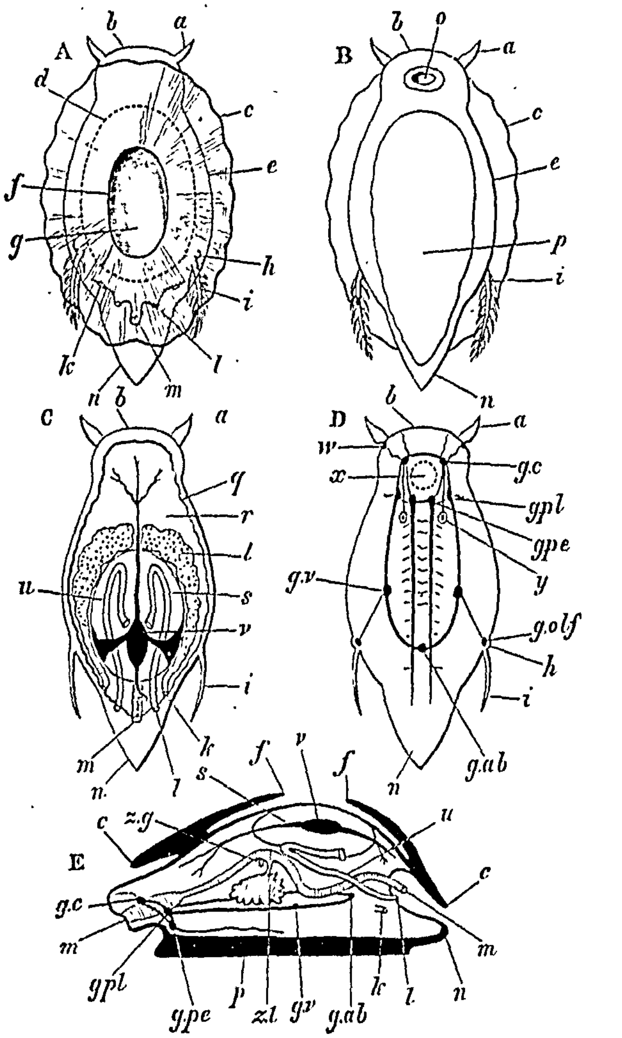

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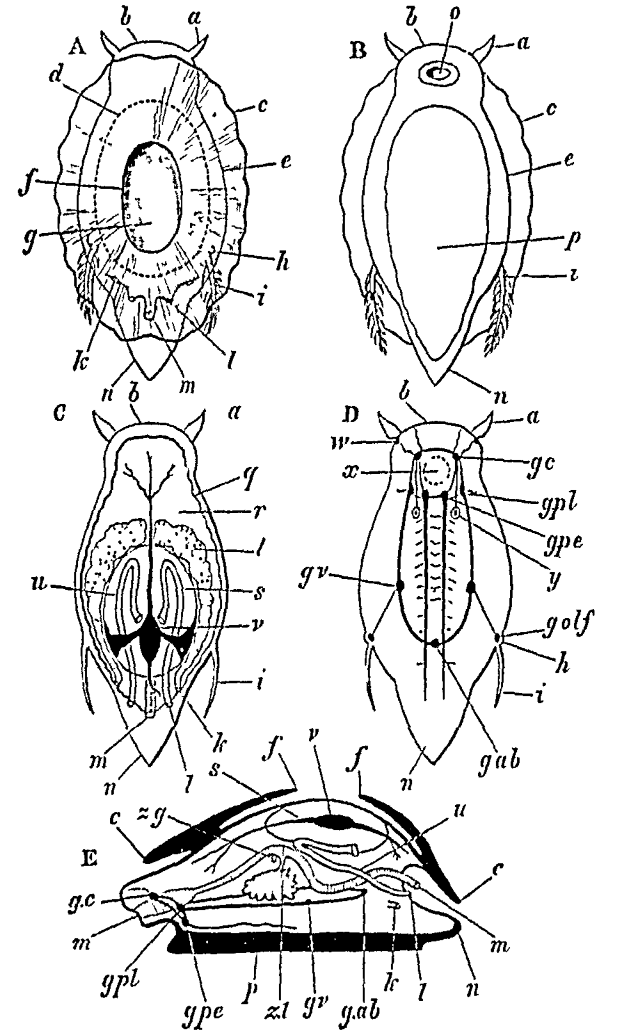

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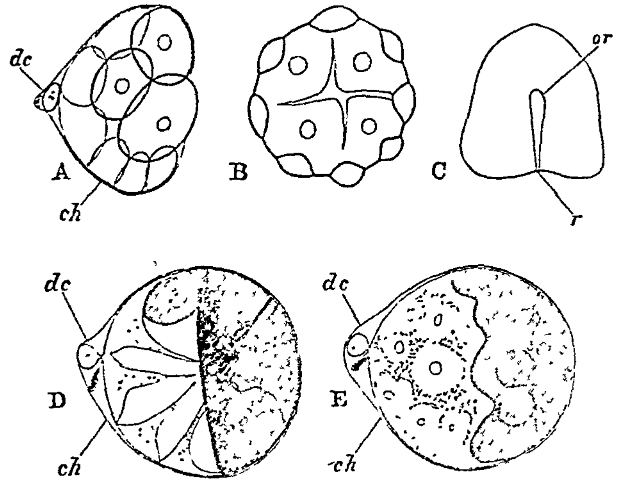

FIG. 3.—Development of the Pond-Snail, *Limnæus stagnalis* (after Lankester, 15). *dc*, directive corpuscles (præseminal outcast cells); *ch*, egg-envelope or chorion; *or*, oral end of the blastopore; *r*, anal end of the blastopore. A. Formation of the Diblastula by the invagination of larger cells into the area of smaller cells (optical section). B. View of the same specimen from the surface of invagination; the smaller cells are seen at the periphery; by division they will multiply and extend themselves over the four larger cells. C. Fully-formed Diblastula, surface view to show the elongated form of the orifice of invagination or blastopore; its middle portion closes up and coincides with the region of the foot; the extremity, *or*, coincides with the mouth and stomodæum, the opposite extremity, *r*, with the anus. D. Optical section of an embryo a little older than A. E. Surface view of the same embryo.

a pair of closed vesicles containing each a calcareous concretion and acting as auditory organs; these are known as OTOCYSTS (D, *y*). They are situated behind the mouth in the foremost portion of the foot. At the base of each cephalic tentacle is a pigmented eye-spot—the CEPHALIC EYE (D, *w*). The OSPHRADIUM (*h*), or peculiar patch of olfactory epithelium at the base of the ctenidium, has already been mentioned.

To the scheme thus exhibited of the possible organization of the ancestral Mollusc we shall now add a sketch of the mode in which this form of body and series of internal organs are developed from the egg.

The egg-cell of Mollusca is either free from food material —a simple protoplasmic corpuscle—or charged with food material to a greater or less extent. Those cases which appear to be most typical—that is to say, which adhere to a

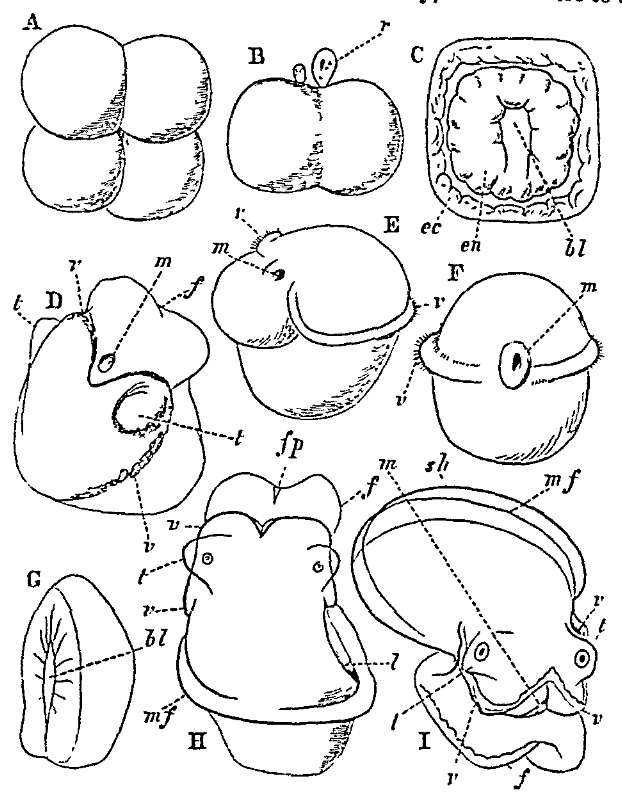

FIG. 4.—Development of the Pond-Snail, *Limnæus stagnalis* (after Lankester, 15). *r*, directive corpuscle; *bl*, blastopore; *en*, endoderm or enteric cell layer; *ec*, ectoderm or deric cell-layer; *v*, velum; *m*, mouth; *f*, foot; *t*, tentacles; *fp*, pore in the foot (belonging to the pedal gland?); *mf*, the mantle-flap or limbus pallialis; *sh*, the shell; *l*, the sub-pallial space, here destined to become the lung. A. First four cells resulting from the cleavage of the original egg-cell. B. Side view of the same C. Diblastula stage (see fig. 3), showing the two cell-layers and the blastopore. D, E, F. Trochosphere stage, D older than E or F. G. Three-quarter view of a Diblastula, to show the orifice of invagination of the endoderm or blastopore, *bl*. H, I. Veliger stage later than D. (Compare fig. 70 and fig. 72***).

procedure which was probably common at one time to all then existing Mollusca, and which has been departed from

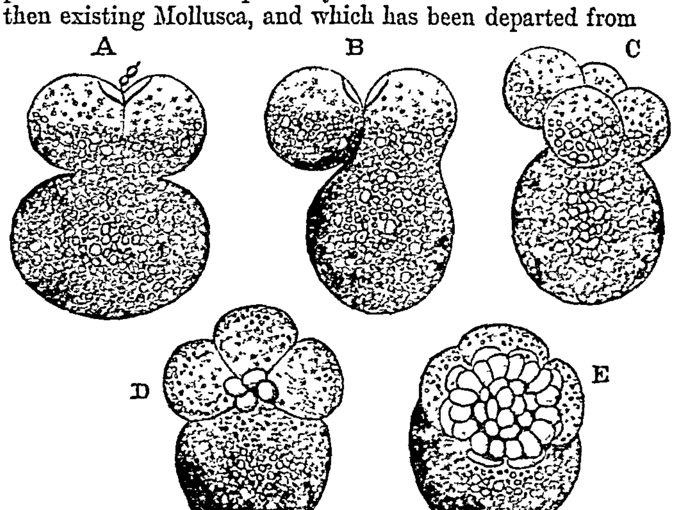

FIG. 5.—Early stages of division of the fertilized egg-cell in *Nassa mutabilis* (from Balfour, after Bobretzky). A. The egg-cell has divided into two spheres, of which the lower contains more food-material, whilst the upper is again incompletely divided into two smaller spheres. Resting on the dividing upper sphere are the eight-shaped "directive corpuscles," better called "præseminal outcast cells or apoblasts," since they are the result of a cell-division which affects the egg-cell before it is impregnated, and are mere refuse, destined to disappear. B. One of the two smaller spheres is reunited to the larger sphere. C. The single small sphere has divided into two, and the reunited mass has divided into two, of which one is oblong and practically double, as in B. D. Each of the four segment-cells gives rise by division to a small pellucid cell. E. The cap of small cells has increased in number by repeated formation of pellucid cells in the same way, and by division of those first formed. The cap will spread over and enclose the four segment-cells, as in fig. 3, A, B.

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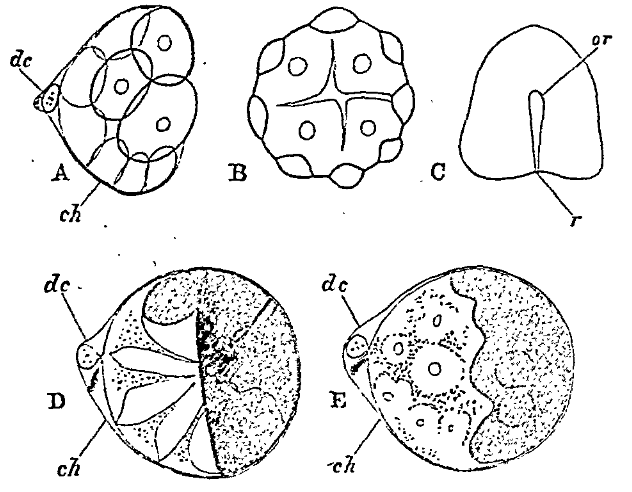

FIG. 3.—Development of the Pond-Snail, *Limnæus stagnalis* (after Lankester, 15). *dc*, directive corpuscles (præseminal outcast cells); *ch*, egg-envelope or chorion; *or*, oral end of the blastopore; *r*, anal end of the blastopore. A. Formation of the Diblastula by the invagination of larger cells into the area of smaller cells (optical section). B. View of the same specimen from the surface of invagination; the smaller cells are seen at the periphery; by division they will multiply and extend themselves over the four larger cells. C. Fully-formed Diblastula, surface view to show the elongated form of the orifice of invagination or blastopore; its middle portion closes up and coincides with the region of the foot; the extremity, *or*, coincides with the mouth and stomodæum, the opposite extremity, *r*, with the anus. D. Optical section of an embryo a little older than A. E. Surface view of the same embryo.

a pair of closed vesicles containing each a calcareous concretion and acting as auditory organs; these are known as OTOCYSTS (D, *y*). They are situated behind the mouth in the foremost portion of the foot. At the base of each cephalic tentacle is a pigmented eye-spot—the CEPHALIC EYE (D, *w*). The OSPHRADIUM (*h*), or peculiar patch of olfactory epithelium at the base of the ctenidium, has already been mentioned.

To the scheme thus exhibited of the possible organization of the ancestral Mollusc we shall now add a sketch of the mode in which this form of body and series of internal organs are developed from the egg.

The egg-cell of Mollusca is either free from food material —a simple protoplasmic corpuscle—or charged with food material to a greater or less extent. Those cases which appear to be most typical—that is to say, which adhere to a

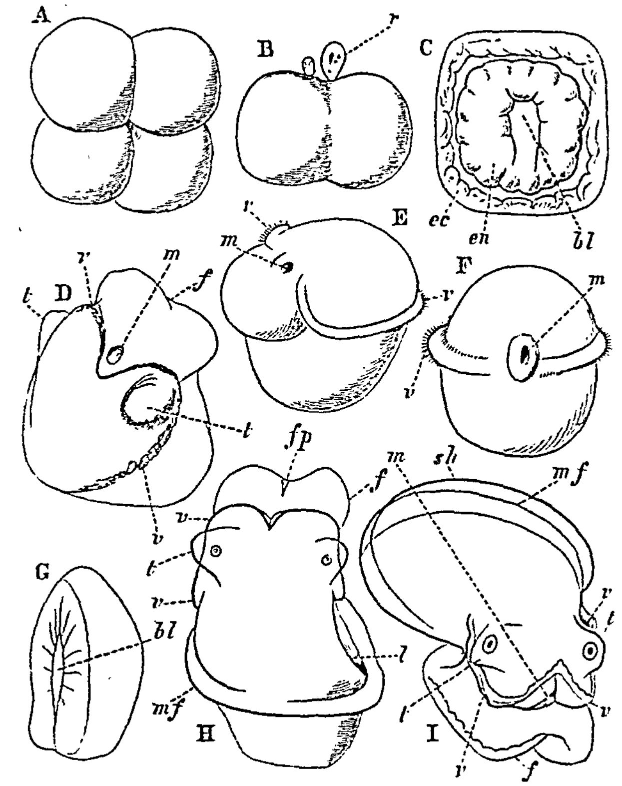

FIG. 4.—Development of the Pond-Snail, *Limnæus stagnalis* (after Lankester, 15). *r*, directive corpuscle; *bl*, blastopore; *en*, endoderm or enteric cell layer; *ec*, ectoderm or deric cell-layer; *v*, velum; *m*, mouth; *f*, foot; *t*, tentacles; *fp*, pore in the foot (belonging to the pedal gland?); *mf*, the mantle-flap or limbus pallialis; *sh*, the shell; *l*, the sub-pallial space, here destined to become the lung. A. First four cells resulting from the cleavage of the original egg-cell. B. Side view of the same. C. Diblastula stage (see fig. 3), showing the two cell-layers and the blastopore. D, E, F. Trochosphere stage, D older than E or F. G. Three-quarter view of a Diblastula, to show the orifice of invagination of the endoderm or blastopore, *bl*. H, I. Veliger stage later than D. (Compare fig. 70 and fig. 72***).

procedure which was probably common at one time to all then existing Mollusca, and which has been departed from

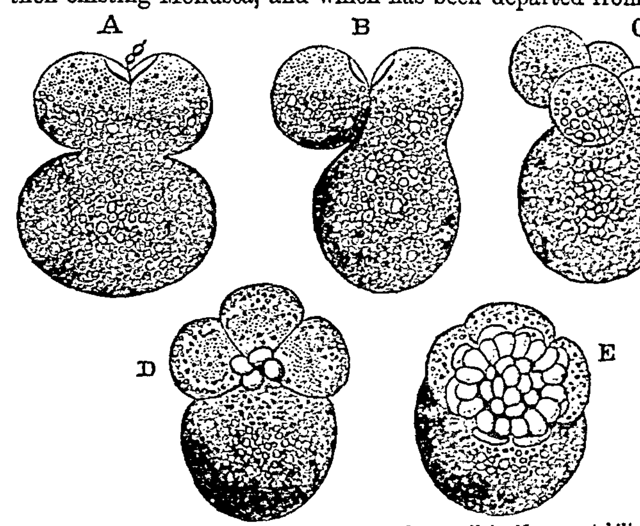

FIG. 5.—Early stages of division of the fertilized egg-cell in *Nassa mutabilis* (from Balfour, after Bobretzky). A. The egg-cell has divided into two spheres, of which the lower contains more food-material, whilst the upper is again incompletely divided into two smaller spheres. Resting on the dividing upper sphere are the eight-shaped "directive corpuscles," better called "præseminal outcast cells or apoblasts," since they are the result of a cell-division which affects the egg-cell before it is impregnated, and are mere refuse, destined to disappear. B. One of the two smaller spheres is reunited to the larger sphere. C. The single small sphere has divided into two, and the reunited mass has divided into two, of which one is oblong and practically double, as in B. D. Each of the four segment-cells gives rise by division to a small pellucid cell. E. The cap of small cells has increased in number by repeated formation of pellucid cells in the same way, and by division of those first formed. The cap will spread over and enclose the four segment-cells, as in fig. 3, A, B.

only in later and special lines of descent—show approxi-

B), in an equatorial position. As growth proceeds, one hemisphere remains relatively small, the other elongates and enlarges. Both mouth and anus are placed in the larger area; the smaller area is the prostomium simply; the ciliated band is therefore in front of the mouth. The larval form thus produced is known as the Trochosphere. It exactly agrees with the larval form of many Chætopod worms and other Cœlomata. Most remarkable is its agreement with the adult form of the Wheel animalcules or Rotifera, which retain the præ-oral ciliated band as their chief organ of locomotion and prehension throughout life. So far the young Mollusc has not reached a definitely Molluscan stage of development, being only in a condition common to it and other Cœlomata. It now passes to the veliger phase, a definitely Molluscan form, in which the disproportion between the area in front of the ciliated circlet and that behind it is very greatly increased, so that the former is now simply an emarginated region of the head fringed with cilia (fig. 8; fig. 6, F; fig. 7, F; and fig. 60, A). It is termed the "velum," and is frequently drawn out into lobes and processes. As in the Rotifera, it serves the veliger larva as an organ of locomotion.

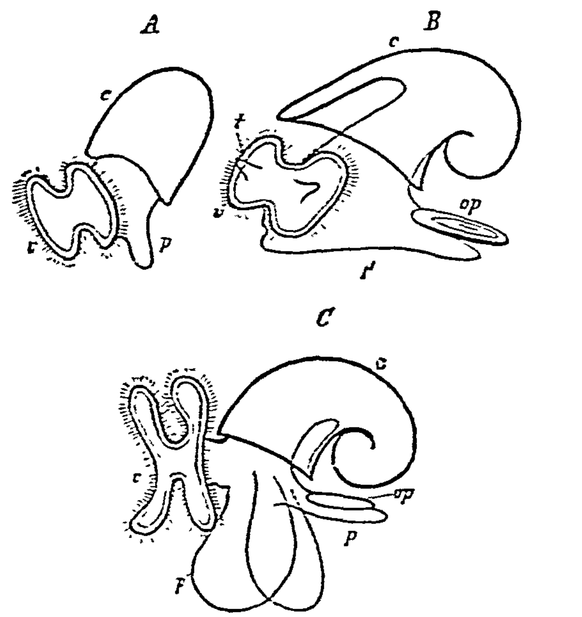

FIG. 8.—"Veliger" embryonic form of Molluscs (from Gegenbaur). *v*, velum; *c*, visceral dome with dependent mantle-skirt; *p*, foot; *t*, cephalic tentacles; *op*, operculum. A. Earlier, and B, later. Veliger of a Gastropod. C. Veliger of a Pteropod showing lobe-like processes of the velum and the great paired outgrowths of the foot.

In a very few Molluscs, but notably in the Common Pond-Snail, the emarginated bilobed velum is retained in full proportions in adult life (fig. 70), having lost its marginal fringe of specially long cilia and its locomotor function. The body of the Veliger is characterized by the development of the visceral hump on one surface, and by that of the foot on the other. Growth is greater in the vertical dorso-ventral axis than in the longitudinal oro-anal axis; consequently the foot is relatively small and projects as a blunt process between mouth and anus, which are not widely distant from one another, whilst the antipedal area projects in the form of a great hump or dome. In the centre of this antipedal area there has appeared (often at a very early period) a gland-like depression or follicle of the integument (fig. 6, C, *sk*; fig. 7, E, F, *shgl*; fig. 60, B; fig. 68, *shs*; fig. 72***, *ss*). This is the primitive shell-sac discovered by Lankester (18) in 1871, and shown by him to precede the development of the permanent shell in a variety of Molluscan types. The cavity of this small sac becomes filled by a horny substance, and then it very usually disappears, whilst a delicate shell, commencing from this spot as a centre, forms and spreads upon the surface of the visceral dome.

The embryonic shell-sac or shell-gland represents in a transient form, in the individual development of most Mollusca, that condition of the shell-forming area which we have sketched above in the schematic Mollusc. In very few instances (in Chiton, and probably in Limax), as we shall see below, the *primitive shell-sac* is retained and enlarged as the permanent shell-forming area. It is supplanted in other Molluscs by a *secondary shell-forming area*, namely, that afforded by the free surface of the visceral hump, the shell-forming activity of which extends even to the surface of the depending mantle-skirt. Accordingly, in most Mollusca the *primitive shell* is represented only by the horny plug of the primitive shell-sac. The permanent shell is a new formation on a new area, and should be distinguished as a *secondary shell.*

The ctenidia, it will be observed, have not yet been mentioned, and they are indeed the last of the characteristic Molluscan organs to make their appearance. Their possible relation to the præ-oral and post-oral ciliated bands of embryos similar to the Trochosphere are discussed by the writer in the *Quart. Jour. Micr. Sci.*, vol. xvii. p. 423. The Veliger, as soon as its shell begins to assume definite shape, is no longer of a form common to various classes of Mollusca, but acquires characters peculiar to its class. At this point, therefore, we shall for the present leave it.

SYSTEMATIC REVIEW OF THE CLASSES AND ORDERS OF MOLLUSCA.

We are now in a position to pass systematically in review the various groups of Mollusca, showing in what way they conform to the organization of our schematic Mollusc, and in what special ways they have modified or even suppressed parts present in it, or phases in the representative embryonic history which has just been sketched. It will be found that the foot, the shell, the mantle-skirt, and the ctenidia, undergo the most remarkable changes of form and proportionate development in the various classes —changes which are correlated with extreme changes and elaboration in the respective functions of those parts.

Division of the Phylum into two Branches.—The Mollusca are sharply divided into two great lines of descent or branches, according as the prostomial region is atrophied on the one hand, or largely developed on the other.

The probabilities are in favour of any ancestral form—the hypothetical archi-Mollusc which connected the Mollusca with their non-Molluscan forefathers—having possessed, as do all the more primitive forms of Cœlomata, a well-marked prostomium, and consequently a head. The one series of Mollusca descended from the primitive head-bearing Molluscs have acquired an organization in which the Molluscan characteristics have become modified in definite relation to a sessile inactive life. As the most prominent result of the adaptation to such sessile life they exhibit an atrophy of the cephalic region. They form the branch LIPOCEPHALA—the mussels, oysters, cockles, and clams. The other series have retained an active, in many cases a highly aggressive, mode of life; they have, correspondingly, not only retained a well-developed head, but have developed a special aggressive organ in connexion with the mouth, which, on account of its remarkable nature and the peculiarities of the details of its mechanism, serves to indicate a very close genetic connexion between all such animals as possess it. This remarkable organ is the odontophore, consisting of a lingual ribbon, rasp, or radula, with its cushion and muscles. On account of the possession of this organ this great branch of the Molluscan phylum may be best designated GLOSSOPHORA. Any term

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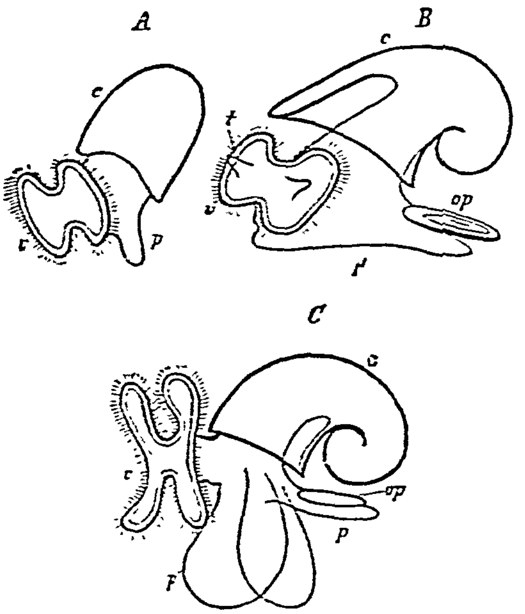

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1.0.1, the central tooth being absent and the lateral teeth peculiarly long and connected with muscles. The term Ptenoglossa (fig. 9, D) is applied to those Glossophora in which the radula presents no median tooth, but an indefinite and large number of admedian teeth, giving the formula x.0.x. When the admedian teeth are indefinite (forty to fifty), and a median tooth is present, the term Myriaglossa is applied (formula, x.1.x). It must be understood that the pieces or teeth thus formulated may themselves vary much in form, being either flat plates, or *denticulated, hooked, or spine-like bodies.* We shall revert to the terms thus explained in the systematic descriptions of the groups of Glossophora.

The muscular development in connexion with the whole buccal mass, and with each part of the radular apparatus, is exceedingly complicated,—as many as twenty distinct muscles having been enumerated in connexion with this organ. In addition to the radula, and correlated with its development, we find almost universally present in the Glossophora a pair of horny jaws (usually calcified) developed as cuticular productions upon the epidermis of the lips (fig. 9, A, *b*). The radula and the shelly jaws of the Glossophora enable their possessors not only to voraciously attack vegetable food, but the radula is used in some instances for boring the shells of other Mollusca, and the jaws for crushing the shells of Crustacea, and for wounding even Vertebrata.

PHYLUM MOLLUSCA.

BRANCH A.—*GLOSSOPHORA.*

Characters.—Mollusca with head-region more or less prominently developed; always provided with a peculiar rasping-tongue—the odontophore—rising from the floor of the buccal cavity.

The Glossophora comprise three classes, chiefly distinguished from one another by the modifications of the foot.

Class I.—**GASTROPODA.**

Characters.—Glossophora in which (with special exception of swimming forms) the FOOT is simple, median in position, and flattened so as to form a broad sole-like surface, by the contractions of which the animal crawls, often divided into three successive regions—the pro-, meso-, and meta-podium—by lateral constrictions.

The Gastropoda exhibit two divergent lines of descent indicated by the term sub-class (see p. 649).

Sub-class 1.—GASTROPODA ISOPLEURA.

Characters.—Gastropoda in which not only the head and foot but also the visceral dome with its contents and the mantle retain the primitive BILATERAL SYMMETRY of the archi-Mollusc. The anus retains its position in the median line at the posterior end of the body. The whole visceral mass together with the foot is elongated, so that the axis joining mouth and anus is relatively long, whilst the dorso-pedal axis at right angles to it is short. The CTENIDIA, the NEPHRIDIA, GENITAL DUCTS, and CIRCULATORY ORGANS are paired and bilaterally symmetrical. The pedal and visceral NERVE-CORDS are straight, parallel with one another, and all extend the whole length of the body; the ganglionic enlargements are feebly or not at all developed. The Isopleura comprise three orders.

Order 1.—**Polyplacophora** (the Chitons).

Characters.—Gastropoda Isopleura with a metameric repetition of the shell to the number of eight. The shells of the primitive type are partially or wholly concealed in shell-sacs comparable to the single embryonic shell-sac of other Mollusca. On the surface of the mantle-flap numerous calcified spines and knobs are frequently developed. The ctenidia are of the typical form, small in size and metamerically repeated along the sides of the body to the

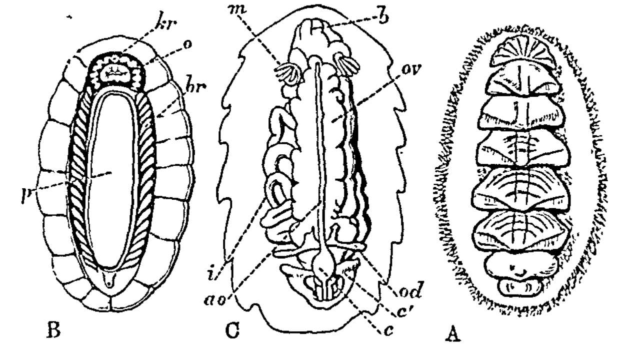

FIG. 10.—Three views of Chiton. A. Dorsal view of *Chiton Wosnessenksii*, Midd., showing the eight shells. (After Middendorf.) B. View from the pedal surface of a species of Chiton from the Indian Ocean. *p*, foot; *o*, mouth (at the other end of the foot is seen the anus raised on a papilla); *kr*, oral fringe; *br*, the numerous ctenidia (branchial plumes); spreading beyond these, and all round the animal, is the mantle-skirt. (After Cuvier.) C. The same species of Chiton, with the shells removed and the dorsal integument reflected. *b*, buccal mass; *m*, retractor muscles of the buccal mass; *ov*, ovary; *od*, oviduct; *i*, coils of intestines; *ao*, aorta; *c'*, left auricle; *c*, ventricle.

number of sixteen or more; an osphradium or area of "olfactory epithelium" (Spengel) is found at the base of each ctenidium. The other organs are not subject to metameric repetition. The odontophore is highly developed; the teeth of the lingual ribbon are varied in form,—several in each transverse row (fig. 9, E). Paired genital ducts distinct from the paired nephridia are present.

The order Polyplacophora contains but one family, the *Chitonidæ*, with the genera: *Chiton*, Lin. (figs. 10, 15, &c.); *Cryptochiton*, Midd., 1847; and *Cryptoplax* (= *Chitonellus*), Blainv., 1818.

Order 2.—**Neomeniæ.**

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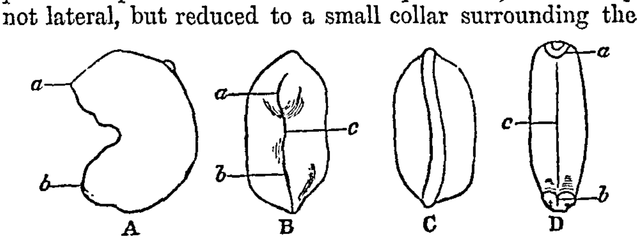

FIG. 11.—*Neomenia carinata*, Tullberg (after Tullberg). A. Lateral view. B. Ventral view. C. Dorsal view. D. Ventral view of a more extended specimen. *a*, anterior; *b*, posterior extremity; *c*, furrow, in which the narrow foot is concealed.

anus; ctenidia represented by a symmetrical group of branchial filaments on either side of the anus; foot very narrow, sunk in a groove; odontophore feebly developed, but the radula many-toothed; gonads placed in the pericardium discharging by the nephridia; no special generative ducts.

The order Neomeniæ contains the two genera *Neomenia*, Tullberg (*Solenopus, Sars*) (fig. 11); and *Proneomenia*, Hubrecht.

Order 3.—**Chætoderma.**

Characters.—Gastropoda Isopleura devoid of a shell which is replaced by numerous minute calcareous s

FIG. 12.—*Chætoderma nitidulum*, Loven (after Graff). The cephalic enlargement is to the left, the anal chamber (reduced pallial chamber, containing the concealed pair of ctenidia) to the right.

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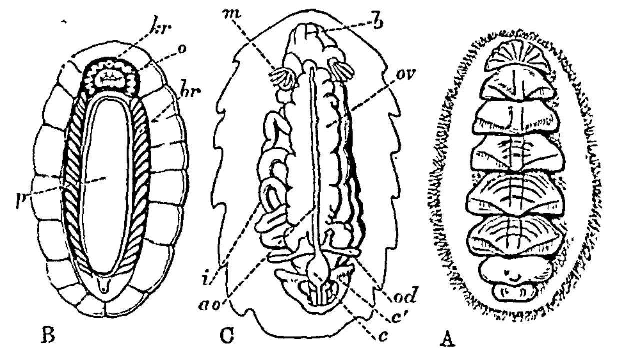

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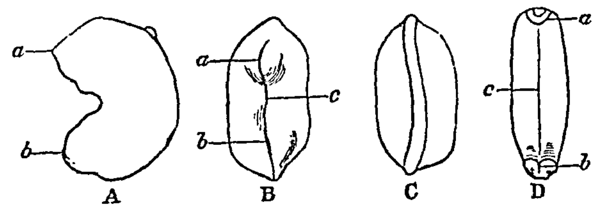

Fig. 11.—*Neomenia carinata*, Tullberg (after Tullberg). A. Lateral view. B. Ventral view. C. Dorsal view. D. Ventral view of a more extended specimen. *a*, anterior; *b*, posterior extremity; *c*, furrow, in which the narrow foot is concealed.

anus; ctenidia represented by a symmetrical group of branchial filaments on either side of the anus; foot very narrow, sunk in a groove; odontophore feebly developed, but the radula many-toothed; gonads placed in the pericardium discharging by the nephridia; no special generative ducts.

The order Neomeniæ contains the two genera *Neomenia*, Tullberg (*Solenopus*, *Sars*) (fig. 11); and *Proneomenia*, Hubrecht.

Order 3.—**Chætoderma.**

Characters.—Gastropoda Isopleura devoid of a shell which is replaced by numerous minute calcareous s[illegible]

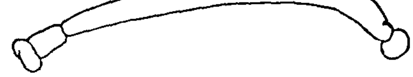

Fig. 12.—*Chætoderma nitidulum*, Loven (after Graff). The cephalic enl[illegible] ment is to the left, the anal chamber (reduced pallial chamber, [illegible] the concealed pair of ctenidia) to the right.

standing up like hairs on the surface of the body; bod

nephridia of Conchifera (organ of Bojanus), the internal aperture lies near the external. From the folded stem of the nephridium very numerous secreting cæca are given off, —omitted in the diagram (fig. 14, D), but accurately drawn in fig. 15. The sexes in Chiton are distinct, and the ovary or testis, as the case may be, though lying in and filling a chamber of the original cœlom, does not discharge into the pericardium, but has its own ducts, which pass to the exterior just in front of those of the nephridia (fig. 14, D, *g*, and fig. 16). In this respect Chiton is less primitive than the other Isopleura, and even than some other Gastropods (the Zygobranchia), and some Conchifera (Spondylus, &c.), which have no special genital apertures, but make use of the nephridia for this purpose. In *Chiton discrepans*, in which there are sixteen pairs of ctenidia, the orifices of the nephridia are coincident with the sixteenth pair of ctenidia, those of the genital ducts with a point between the thirteenth and fourteenth ctenidia.

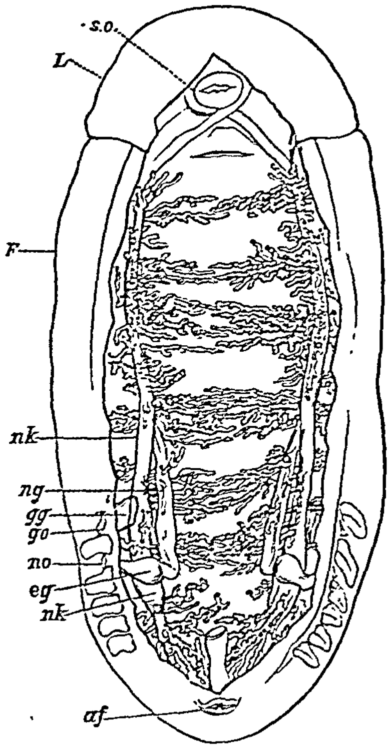

FIG. 15.—Dissection of the renal organs (nephridia) of *Chiton siculus*, after Haller (*Arbeiten, Zool. Instit.*, Vienna, 1882). *F*, foot; *L*, edge of the mantle not removed in the front part of the specimen; *s.o.*, œsophagus; *af*, anus; *gg*, genital duct; *go*, external opening of the same; *eg*, stem of the nephridium leading to *no*, its external aperture; *nk*, reflected portion of the nephridial stem; *ng*, fine cæca of the nephridium, which are seen ramifying transversely over the whole inner surface of the pedal muscular mass.

In the Neomeniæ and Chætoderma the nephridia are short and wide (*N* in fig. 14, A, B, C), and function as excretory ducts for the genital products, the gonads being lodged in the long pericardium. Their separate or united apertures open near the anus into the small chamber formed by the restriction of the mantle-skirt to the immediate neighbourhood of the anus.

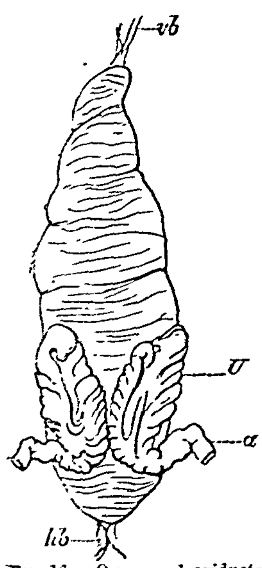

FIG. 16.—Ovary and oviducts of *Chiton siculus* (after Haller, *loc. cit.*). *vb*, *hb*, anterior and posterior suspensor of the ovary; *U*, uterus (enlarged part of oviduct); *a*, oviduct.

The nervous system of the Gastropoda Isopleura is represented in the diagram fig. 17. In all it is important to observe that nerve-ganglion cells are by no means limited to special swellings—the ganglia—but are abundant along the whole course of the four great longitudinal trunks. This is a primitive character comparable to that presented by the nerve-cords of Nemertine worms, and of the Arthropod Peripatus. Higher differentiation in other Mollusca leads to predominance if not an exclusive presence of nerve-*fibres* in the cords, and of nerve-*ganglion cells* in the specialized ganglia. The numerous transverse connexions of the pedal nerve-cords in Chiton and Neomenia (seen also in Fissurella (fig. 36) and some other Gastropods) are comparable to the transverse connexions of the ventral nerve-cords of Chætopod worms and Arthropods. In the abundance of the nervous network connected with its longitudinal nerve-tracts, Chiton appears to retain something of the early condition of the Cœlomate nervous system when it had the form of a sub-epidermic network or nerve-tunic (seen more clearly in Planarians and some Nemertines), and when the concentration into definitely compacted cords had not set in.

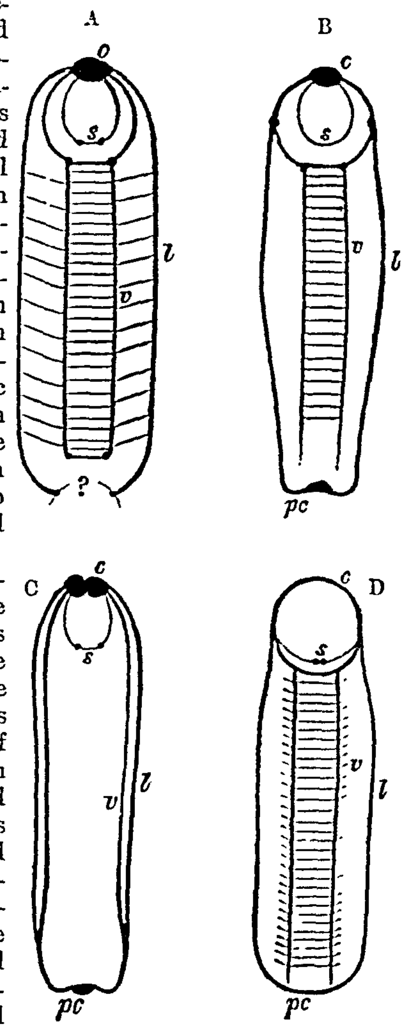

FIG. 17.—Diagrams of the nervous system of Isopleura (after Hubrecht, *loc. cit.*). *c*, cerebral ganglia; *s*, sublingual ganglia; *v*, pedal (ventral) nerve-cord; *l*, visceral (lateral) nerve-cord; *pc*, post-anal junction of the visceral nerve-cords. A. Proneomenia. B. Neomenia. C. Chætoderma. D. Chiton.

Ganglia are, however, distinguishable upon the nervous cords of Chiton (fig. 18). The cerebral ganglia are not distinguishable as such, but a pair of buccal ganglia (B in fig. 18) are developed on two connectives which pass forward from the cerebral region to the great muscular mass of the mouth. These buccal ganglia are special developments connected with the special muscularity of the lips and odontophore, and are found in all Glossophora, but not in the Lipocephala. Such special ganglia related to special organs (and not introduced in our schematic Mollusc, fig. 1) we find in connexion with the siphons of the Lipocephala, and in various positions upon the visceral nerve-cords of other Mollusca, both Glossophora and Lipocephala. A pair of pedal ganglia little developed (*p* in fig. 18) and a special group of sublingual ganglia are present in Chiton. On the whole, the nervous system of the Isopleura is exceedingly simple and archaic, whilst it does not well serve as a type with which to compare that of other Mollusca on account of the small amount of concentration of its nerve-ganglion cells into ganglia, such as we find well developed in other forms.

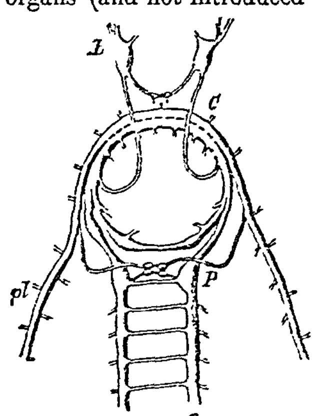

FIG. 18.—Anterior part of the nervous system of *Chiton cinereus*, in more detail (from Gegenbaur, *Elements of Comp. Anatomy*). *B*, buccal ganglia (concerned with the odontophore); *C*, cerebral nerve-mass; *P*, pedal ganglion and commencement of pedal nerve-cord; *pl*, visceral nerve-cord. The sublingual ganglia are not lettered.

The development of Neomenia and Chætoderma is

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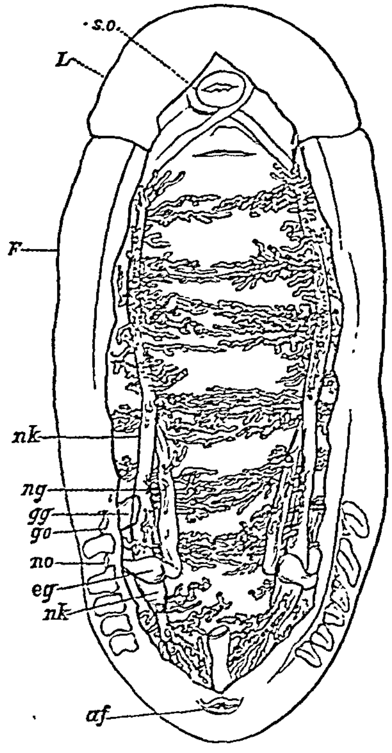

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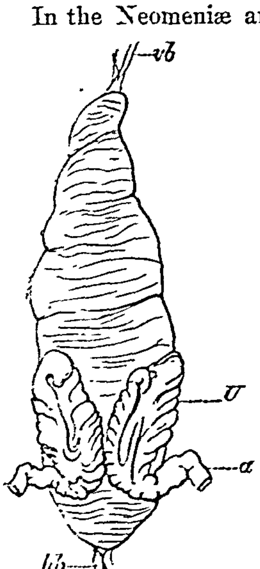

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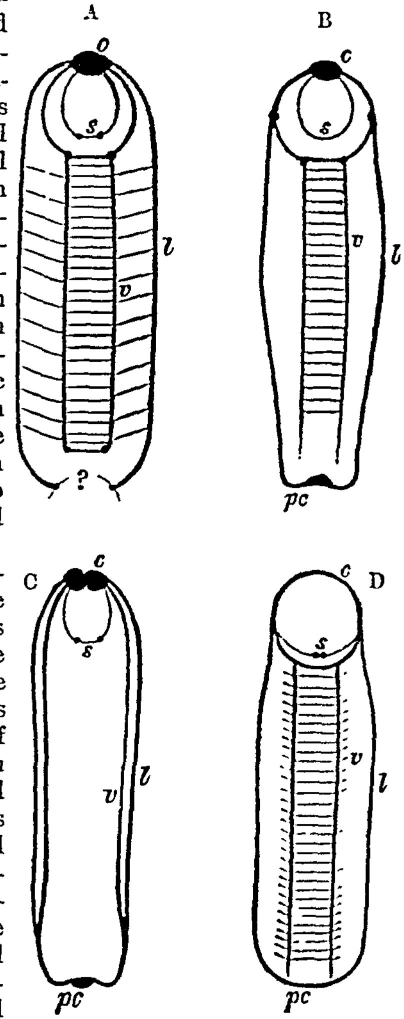

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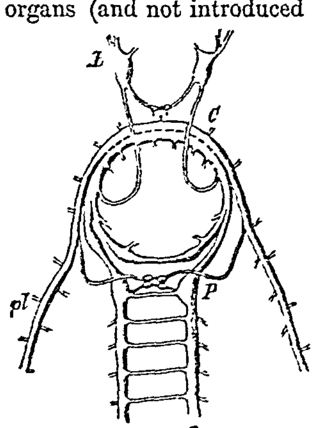

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Branch *a*.—*STREPTONEURA* (Spengel, 1881).

Characters.—Gastropoda Anisopleura in which the visceral "loop" (the conterminous visceral nerves) was adherent to the body-wall and so shared in the torsion of the visceral hump, the right cord crossing above the left so as to form a figure-of-eight (see fig. 19).

The Streptoneura comprise two orders—the Zygobranchia and the Azygobranchia.

Order 1.—Zygobranchia.

Characters.—Streptoneura in which, whilst the visceral torsion is very complete so as to bring the anus into the middle line anteriorly or nearly so, the atrophy of the primitively left-side organs is not carried out. The right and left ctenidia, which have now become left and right respectively, are of equal size, and are placed symmetrically on either side of the neck in the pallial space. Related to them is a simple pair of osphradial patches. Both right

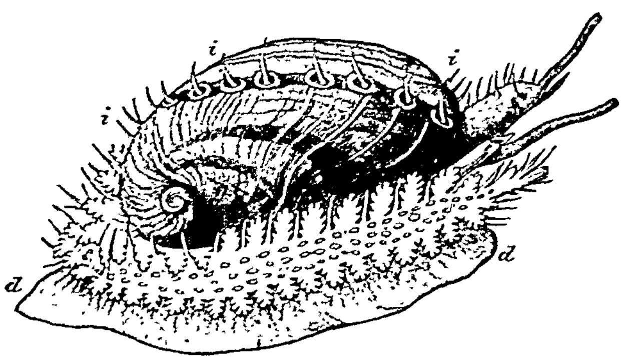

FIG. 23.—*Haliotis tuberculata.* *d*, foot; *i*, tentacular processes of the mantle. (From Owen, after Cuvier.)

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The Zygobranchia comprise three families, arranged in two suborders.

Sub-order 1. *Ctenidiobranchia.*

Character.—Large paired ctenidia acting as gills.

Family 1.—*Haliotidæ.*
Genera: *Haliotis* (Ear-Shell, Ormer in Guernsey); mostly tropical; *Teinotis.*

Family 2.—*Fissurellidæ.*
Genera: *Fissurella* (Key-hole Limpet) (figs. 24, 36), *Emarginula*, *Parmophorus* (fig. 25); mostly tropical.

Sub-order 2. *Phyllidiobranchia.*

Characters.—Ctenidia reduced to wart-like papillæ; special sub-pallial lamellæ, similar to those of the Opisthobranch Pleurophyllidia, perform the function of gills.

Family 3.—*Patellidæ.*
Genera: *Patella* (Limpet, figs. 26, &c.), *Nacella* (Bonnet-Limpet), *Lottia.*

Further Remarks on Zygobranchia.—The Common Limpet is a specially interesting and abundant example of the remarkable order Zygobranchia. A complete and accurate account of its anatomy has yet to be written. Here we have only space for a brief outline. The foot of the Limpet is a nearly circular disc of muscular tissue; in front, projecting from and raised above it, are the head and neck (figs. 26, 30). The visceral hump forms a low conical dome above the sub-circular foot, and standing out all round the base of this dome so as to completely overlap the head and foot, is the circular mantle-skirt. The depth of free mantle-skirt is greatest in front, where the head and neck are covered in by it. Upon the surface of the visceral dome, and extending to the edge of the free mantle-skirt, is the conical shell. When the shell is taken away (best effected by immersion in hot water) the surface of the visceral dome is found to be covered by a black-coloured epithelium, which may be removed, enabling the observer to note the position of some organs lying below the transparent integument (fig. 27). The muscular columns (attaching the foot to the shell form a ring incomplete i front, external to which is the mantle-skirt. The limits of th large area formed by the flap o the head and neck (*ecr*) can be traced and we note the anal papilla sh ing through and opening on the rig shoulder, so to speak, of the into the large anterior region of t sub-pallial space. Close to this small renal organ (*i*, mediad) and larger renal organ (*k*, to the ri and posteriorly) are seen, also pericardium (*l*) and a coil of the testine (*int*) embedded in the pact liver.

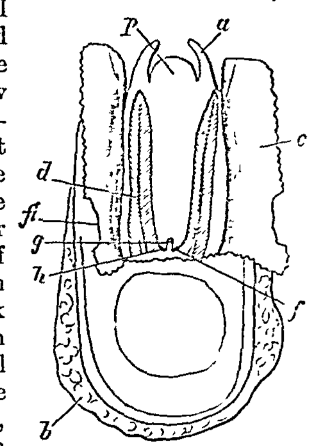

FIG. 24.—Dorsal aspect of a specimen of Fissurella from which the shell has been removed, whilst the anterior area of the mantle-skirt has been longitudinally slit and its side reflected. *a*, cephalic tentacle; *b*, foot; *d*, left (archaic right) gill plume; *e*, reflected mantle-flap; the fissure or hole in the mant traversed by the longitudinal incision; *f*, right (archaic left) dium's aperture; *g*, anus; *h*, (archaic right) aperture of nephridium; *p*, snout. (Original.)

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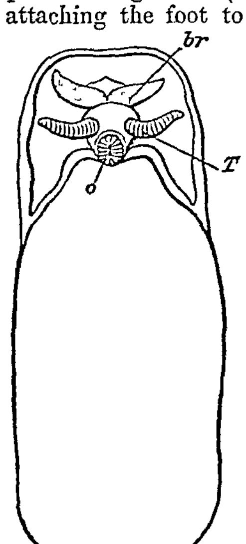

FIG. 25.—Parmophorus, seen from the pedal surface. *o*, mouth; *T*, cephalic tentacle; *br*, one of the two symmetrical gills placed on the neck. (Original.)

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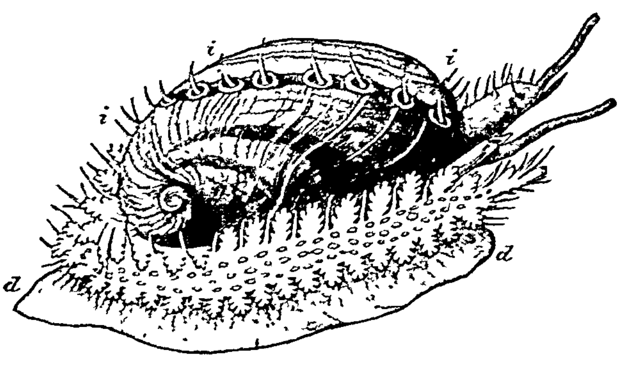

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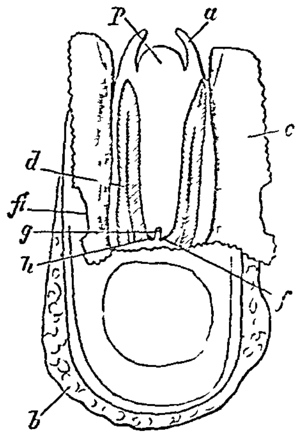

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The existence of two renal organs in Patella, and their relation to the pericardium (a portion of the cœlom), is

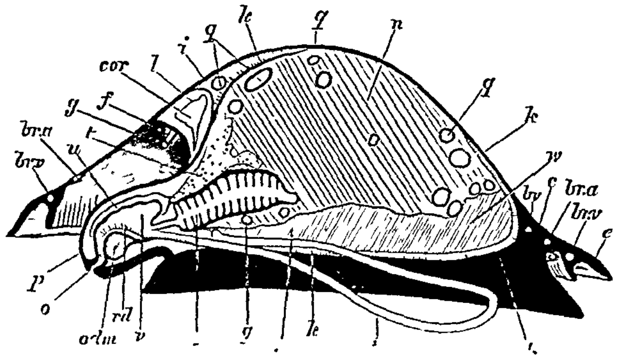

FIG. 31.—Diagram of a vertical antero-postero median section of a Limpet. Letters as in figs. 28, 29, with following additions: *q*, intestine in transverse section; *r*, lingual sac (radular sac); *rd*, radula; *s*, lamellated stomach; *t*, salivary gland; *u*, duct of same; *v*, buccal cavity; *w*, gonad; *br.a*, branchial advehent vessel (artery); *br.v*, branchial efferent vessel (vein); *bv*, blood-vessel; *odm*, muscles and cartilage of the odontophore; *cor*, heart within the pericardium. (Original.)

important. Each renal organ is a sac lined with glandular epithelium (ciliated cells with concretions) communicating

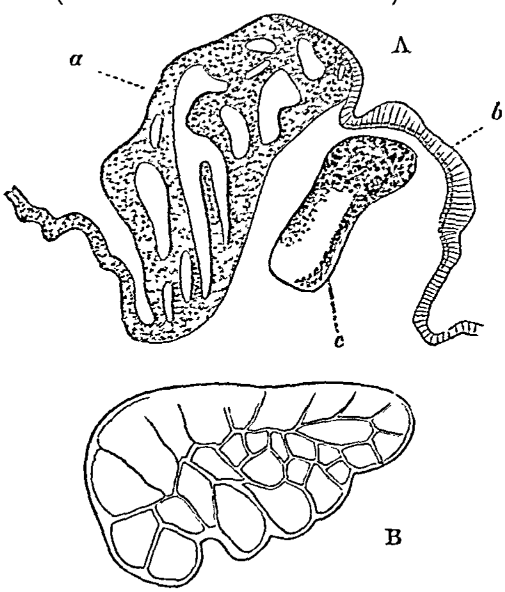

FIG. 32.—A. Section in a plane vertical to the surface of the neck of Patella through *a*, the rudimentary ctenidium (Lankester's organ), and *b*, the olfactory epithelium (osphradium); *c*, the olfactory (osphradial) ganglion. (After Spengel.) B. Surface view of a rudimentary ctenidium of Patella, excised and viewed as a transparent object. (Original.)

with the exterior by its papilla, and by a narrow passage with the pericardium. The connexion with the pericar-

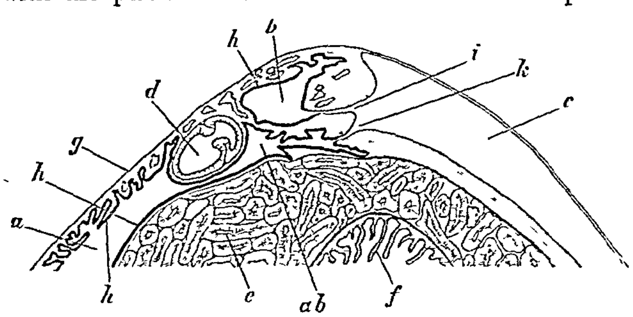

FIG. 33.—Vertical section in a plane running right and left through the anterior part of the visceral hump of Patella, to show the two renal organs and their openings into the pericardium. *a*, large or external or right renal organ; *ab*, narrow process of the same running *below* the intestine and leading by *k* into the pericardium; *b*, small or median renal organ; *c*, pericardium; *d*, rectum; *e*, liver; *f*, manyplies; *g*, epithelium of the dorsal surface; *h*, renal epithelium lining the renal sacs; *i*, aperture connecting the small sac with the pericardium; *k*, aperture connecting the large sac with the pericardium. (From an original drawing by Mr J. T. Cunningham, Fellow of University College, Oxford.)

dium of the smaller of the two renal organs was demonstrated by Lankester in 1867, at a time when the fact that the renal organ of the Mollusca, as a rule, opens into the pericardium, and is therefore a typical nephridium, was not known. Subsequent investigations (27) carried on under the direction of the same naturalist have shown that the larger as well as the smaller renal sac is in communication with the pericardium. The walls of the renal sacs are deeply plaited and thrown into ridges. Below the surface these walls are excavated with blood-vessels, so that the sac is practically a series of blood-vessels covered with renal epithelium, and forming a mesh-work within a space communicating with the exterior. The larger renal sac (remarkably enough, that which is aborted in other Anisopleura) extends between the liver and the integument of the visceral dome very widely. It also bends round the liver as shown in fig. 30, and forms a large sac on half of the upper surface of the muscular mass of the foot. Here it lies close upon the genital body (ovary or testis), and in such intimate relationship with it that, when ripe, the gonad bursts into the renal sac, and its products are carried to the exterior by the papilla on the right side of the anus (Robin, Dall). This fact led Cuvier erroneously to the belief that a d existed leading from the gonad to this papilla. Th position of the gonad, best seen in the diagram in

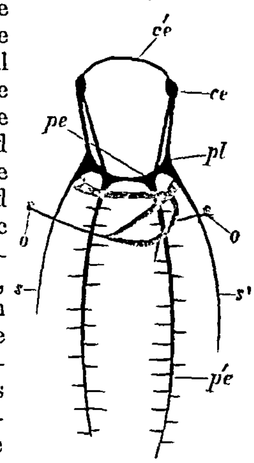

FIG. 34.—Nervous system of Patella; the visceral loop is lightly shaded; the buccal ganglia are omitted. *ce*, cerebral ganglia; *c'e*, cerebral commissure; *pl*, pleural ganglion; *pe*, pedal ganglion; *p'e*, pedal nerve; *s*, *s'*, nerves (right and left) to the mantle; *o*, olfactory ganglion, connected by nerve to the Streptoneurous visceral loop. (After Spengel.)

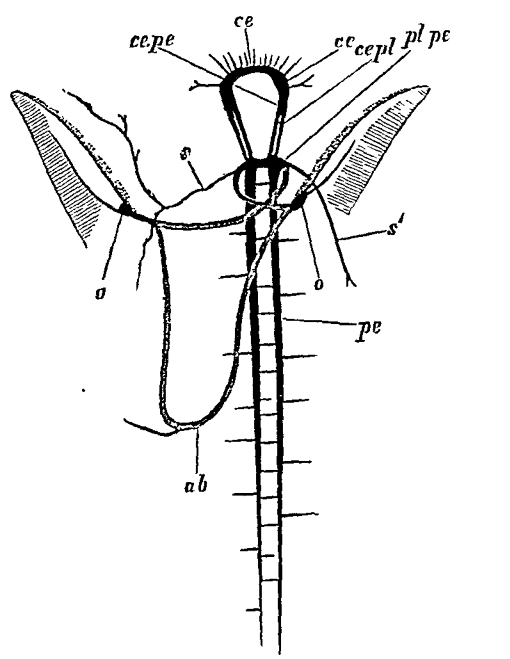

FIG. 35.—Nervous system of Haliotis; the visceral loop is lightly shad the buccal ganglia are omitted. *ce*, cerebral ganglion; *pl.pe*, the fused p and pedal ganglia; *pe*, the right pedal nerve; *ce.pl*, the cerebro-pleural nective; *ce.pe*, the cerebro-pedal connective; *s*, *s'*, right and left nerves; *ab*, abdominal ganglion or site of same; *o*, *o*, right and left olfact ganglia and osphradia receiving nerve from visceral loop. (After Spengel)

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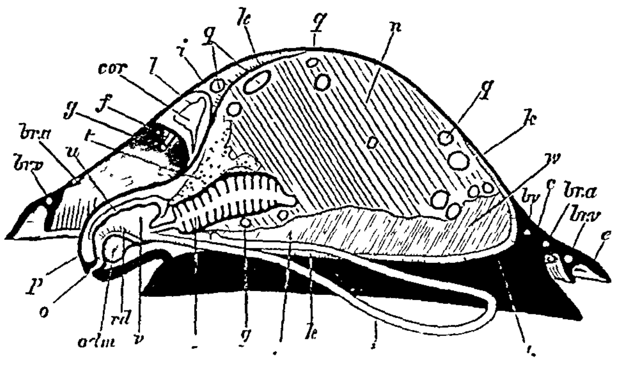
The existence of two renal organs in Patella, and their relation to the pericardium (a portion of the cœlom), is



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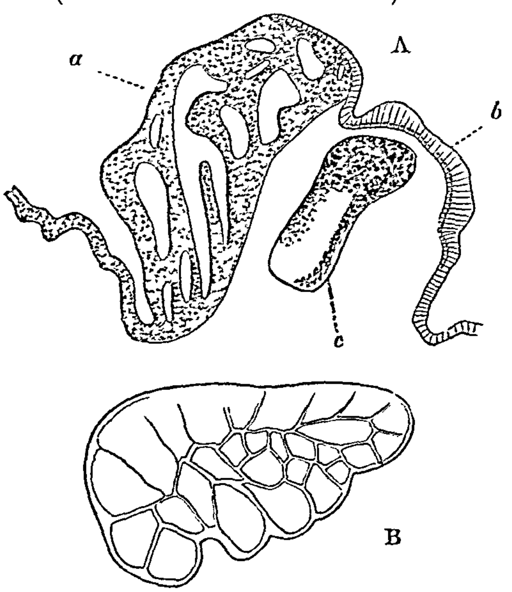

FIG. 32.—A. Section in a plane vertical to the surface of the neck of Patella through *a*, the rudimentary ctenidium (Lankester's organ), and *b*, the olfactory epithelium (osphradium); *c*, the olfactory (osphradial) ganglion. (After Spengel.) B. Surface view of a rudimentary ctenidium of Patella, excised and viewed as a transparent object. (Original.)

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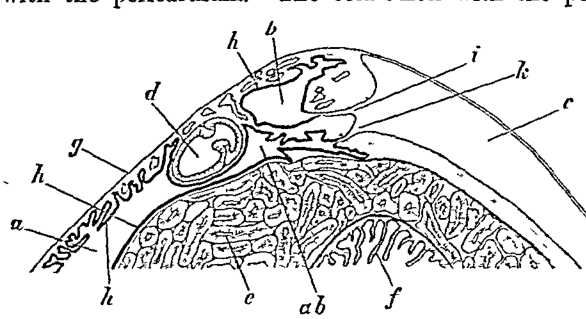

FIG. 33.—Vertical section in a plane running right and left through the anterior part of the visceral hump of Patella, to show the two renal organs and their openings into the pericardium. *a*, large or external or right renal organ; *ab*, narrow process of the same running *below* the intestine and leading by *k* into the pericardium; *b*, small or median renal organ; *c*, pericardium; *d*, rectum; *e*, liver; *f*, manyplies; *g*, epithelium of the dorsal surface; *h*, renal epithelium lining the renal sacs; *i*, aperture connecting the small sac with the pericardium; *k*, aperture connecting the large sac with the pericardium. (From an original drawing by Mr J. T. Cunningham, Fellow of University College, Oxford.)

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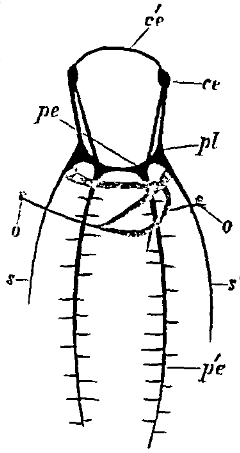

FIG. 34.—Nervous system of Patella; the visceral loop is lightly shaded; the buccal ganglia are omitted. *ce*, cerebral ganglia; *c'e*, cerebral commissure; *pl*, pleural ganglion; *pe*, pedal ganglion; *p'e*, pedal nerve; *s*, *s'*, nerves (right and left) to the mantle; *o*, olfactory ganglion, connected by nerve to the Streptoneurous visceral loop. (After Spengel.)

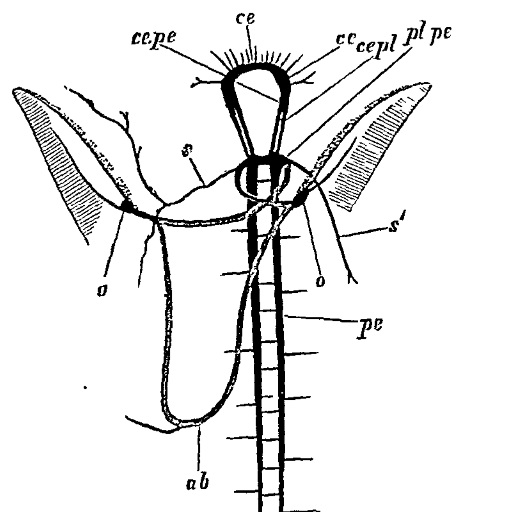

FIG. 35.—Nervous system of Haliotis; the visceral loop is lightly shad[illegible] the buccal ganglia are omitted. *ce*, cerebral ganglion; *pl.pe*, the fused p[illegible] and pedal ganglia; *pe*, the right pedal nerve; *ce.pl*, the cerebro-pleural [con]nective; *ce.pe*, the cerebro-pedal connective; *s*, *s'*, right and left nerves; *ab*, abdominal ganglion or site of same; *o*, *o*, right and left olfact[ory] ganglia and osphradia receiving nerve from visceral loop. (After Speng[el].)

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TABULAR VIEW OF THE SUBDIVISIONS OF THE CLASS GASTROPODA, ARRANGED SO AS TO SHOW THEIR SUPPOSED GENETIC RELATIONSHIPS.

- Class.—GASTROPODA. (*Archisopleurum.*)
  - Sub-class 1.—ISOPLEURA.
    - Order 1.—Polyplacophora.
    - Order 2.—Neomenia.
    - Order 3.—Chætoderma.
  - Sub-class 2.—ANISOPLEURA. (*Archicuthyneurum.*)
    - Branch *a.*—STREPTONEURA. (*Archizygobranchium.*)
      - Order 1.—ZYGOBRANCHIA.
        - Sub-order 1.—*Ctenidiobranchia.*
        - " 2.—*Phyllidiobranchia.*
      - Order 2.—AZYGOBRANCHIA. (*Archiholochlamydum.*)
        - Sect. *a.* *Reptantia.*
          - Sub-order 1.—*Holochlamyda.*
          - " 2.—*Pneumonochlamyda.*
          - " 3.—*Siphonochlamyda.*
        - Sect. *b.* *Natantia.*
          - Sub-order 1.—*Atlantacea.*
          - " 2.—*Carinariacea.*
          - " 3.—*Pterotracheacea.*
    - Branch *b.*—EUTHYNEURA. (*Archiopisthobranchium.*)
      - Order 1.—OPISTHOBRANCHIA. (*Archipalliatum.*)
        - Sect. *a.* *Palliata.*
          - Sub-order 1.—*Ctenidiobranchia.*
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        - Sect. *b.* *Non-Palliata.*
          - Sub-order 1.—*Pygobranchia.*
          - " 2.—*Ceratonota.*
          - " 3.—*Haplomorpha.*
      - Order 2.—PULMONATA. (*Archibasommatum.*)
        - Sub-order 1.—*Basommatophora.*
        - " 2.—*Stylommatophora.*

Family 11.—*Naticidæ.*
Genera: *Natica*, Lam.; *Sigaretus*, Lam.; *Neritopsis*, Gratel.
Family 12.—*Entoconchidæ.*
The single genus and species *Entoconcha mirabilis*, discovered by Joh. Müller in 1851, parasitic in *Synapta digitata*. The adult form is not known.
Family 13.—*Marsenidæ.*
Genera: *Marsenia*, Leach; *Onchidiopsis*, Beck.
Family 14.—*Acmæidæ.*
Genera: *Acmæa*, Eschsch.; *Lottia*, Gr.; (probably these will be found to belong to the Zygobranchia).
Family 15.—*Capulidæ.*
Genera: *Capulus*, Montf.; *Calyptræa*, Lam. (fig. 40); *Trochita*, Schum.
Family 16.—*Littorinidæ.*
Genera: *Littorina* (the Periwinkles, fig. 46); *Modulus*, Gray; *Lacuna*, Turt.; *Rissoa*, Frem.; *Hydrobia*, Hartm.; *Assiminia*, Leach.
Family 17.—*Paludinidæ.*
Genera: *Paludina* (River-Snail) (figs. 7, 21); *Bithynia*, Gray; *Tanalia*, Gray.
Family 18.—*Valvatidæ.*
Genus: *Valvata* (fig. 45), fresh-water.
Family 19.—*Ampullaridæ.*
Genus: *Ampullaria* (can breathe air by means of the walls of the pallial chamber as well as water by the gill; fresh-waters of tropical America, Africa, and East Indies).

Sub-order 2.—*Pneumonochlamyda.*

Characters.—Pallial chamber a lung-sac; no gill; mouth on a rostrum, not a retractile proboscis; terrestrial habit.

Family 20.—*Cyclostomidæ.*
Genera: *Cyclostoma*, Lam.; *Cyclophorus*, Montf.; *Ferussina*, Gratel.; *Pupina*, Vignard.
Family 21.—*Helicinidæ* (radula rhipidoglossate rather than tænioglossate).
Genera: *Stoastoma*, Adams; *Trochatella*, Swains.; *Helicina*, Lam.; *Proserpina*, Guild.
Family 22.—*Aciculidæ.*
Genera: *Acicula*, Hartm.; *Geomelania*, Pfr.

Sub-order 3.—*Siphonochlamyda.*

Characters.—Reptant Azygobranchia with the margin of the mantle drawn out to form a trough-like siphon which notches lip of the shell; shell always spiral; usually an operculum, horn or lamelliform; either a rostrum or a retractile proboscis; exclusive marine; mostly carnivorous.

* *Tænioglossa* (3.1.3).

Family 1.—*Strombidæ.*
Genera: *Strombus*, L.; *Pteroceras*, Lam.; *Rostellaria*, (fig. 43).
Family 2.—*Aporrhaidæ.*
Genus: *Aporrhais*, Da Costa.
Family 3.—*Pedicularidæ.*
Genus: *Pedicularia*, Swains.
Family 4.—*Dolidæ.*
Genera: *Cassis*, Lam.; *Cassidaria*, Lam.; *Dolium*, Lam.; *Ficu* Swains.
Family 5.—*Tritonidæ.*
Genera: *Tritonium*, Cuv. (fig. 42); *Ranella*, Lam.
Family 6.—*Cypræidæ* (the Cowries).
Genera: *Cypræa*, L.; *Ovulum*, Brug. (fig. 41); *Erato*, Risso.

* *Toxiglossa* (1.0.1).

Family 7.—*Conidæ.*
Genus: *Conus*, L.
Family 8.—*Terebridæ.*
Genus: *Terebra*, Adans.
Family 9.—*Pleurotomidæ.*
Genus: *Pleurotoma*, Lam.
Family 10.—*Cancellaridæ.*
Genus: *Cancellaria*, Lam.

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Family 11.—*Muricidæ.*
Genera: *Murex*, L.; *Trophon*, Montf.; *Fusus*, Brug.; *Pyr* Lam. (fig. 38); *Turbinella*, Lam.
Family 12.—*Buccinidæ.*
Genera: *Buccinum*, L.; *Nassa*, Lam. (fig. 5); *Purpura*, (fig. 47); *Concholepas*, Lam.; *Magilus*, Montf.
Family 13.—*Mitridæ.*
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Family 13.—*Mitridæ.*
Genus: *Mitra*, Lam.

the renal organ, and consists of a single auricle receiving blood from the gill, and of a single ventricle which pumps it through the body by an anterior and posterior aorta (see fig. 105). The surface x of the mantle between the rectum and the gill-plume is thrown into folds which in many sea-snails (Whelks, &c.) are very strongly developed. The whole of this surface appears to be active

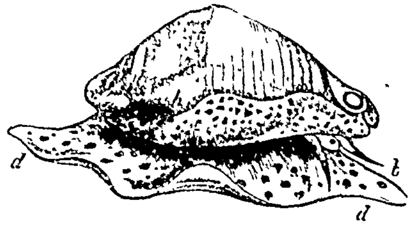

FIG. 41.—Animal and shell of Ovulum. *b*, cephalic tentacles; *d*, foot; *h*, mantle-skirt, which is naturally carried in a reflected condition so as to cover in the sides of the shell.

in the secretion of a mucous-like substance. The single gill-plume *br* lies to the left of the median line in natural position. It corresponds to the right of the two primitive ctenidia in the untwisted archaic condition of the Molluscan body, and does not project freely into the branchial cavity, but its axis is attached (by concrescence) to the mantle-skirt (roof of the branchial chamber). It is rare for the gill-plume of an Anisopleurous Gastropod to stand out freely as a plume, but occasionally this more archaic condition is exhibited, as in Valvata (fig. 45). Next beyond (to the left of) the gill-plume we find the so-called parabranchia, which is here simple, but sometimes lamellated as in Purpura (fig. 47). This organ has, without reason, been supposed to represent the second ctenidium of the typical Mollusc, which it cannot do on account of its position. It should be to the right of the anus were this the case. Recently Spengel has shown that the parabranchia of Gastropods is the typical olfactory organ or osphradium in a highly-developed condition The minute structure of the epithelium which clothes it, as well as the origin of

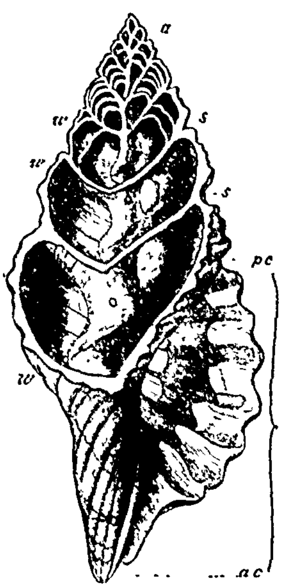

FIG. 42.—Section of the shell of Tritonium, Cuv. *a*, apex; *ac*, siphonal notch of the mouth of the shell; *ac* to *pc*, mouth of the shell; *w*, *w*, whorls of the shell; *s*, *s*, sutures. Occupying the axis, and exposed by the section, is seen the "columella" or spiral pillar. The upper whorls of the shell are seen to be divided into separate chambers by the formation of successively formed "septa." (From Owen.)

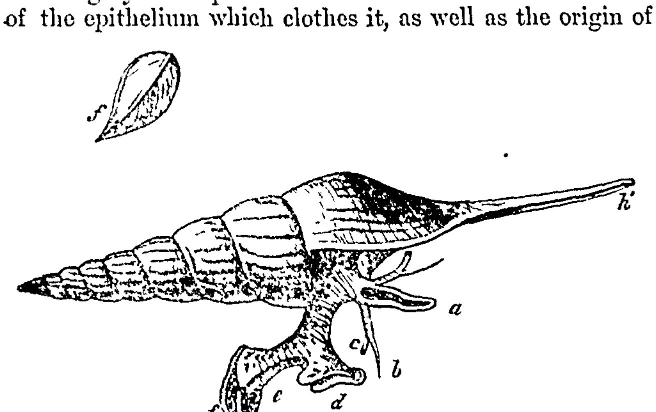

FIG. 43.—Animal and shell of *Rostellaria rectirostris*. *a*, snout or rostrum; *b*, cephalic tentacle; *c*, eye; *d*, propodium and mesopodium; *e*, metapodium; *f*, operculum; *h'*, prolonged siphonal notch of the shell occupied by the siphon, or trough-like process of the mantle-skirt. (From Owen.)

the nerve which is distributed to the parabranchia, proves it to be the same organ which is found universally in Molluscs at the base of each gill-plume, and tests the indrawn current of water by the sense of smell. The nerve to this

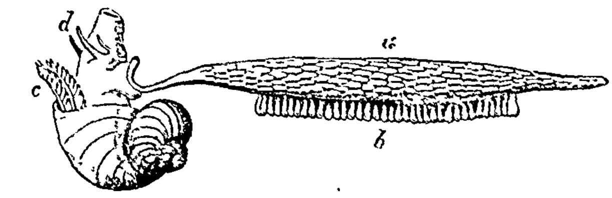

FIG. 44.—Female Janthina, with egg-float (*a*) attached to the foot; *b*, egg-capsules; *c*, ctenidium (gill-plume); *d*, cephalic tentacles.

organ is given off from the superior (original right, see fig. 19) visceral ganglion.

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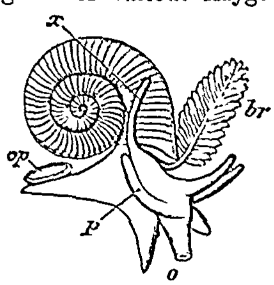

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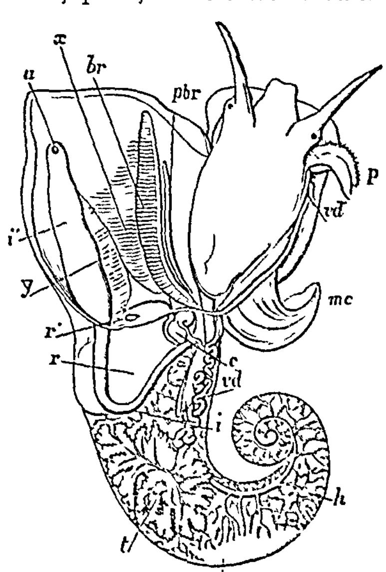

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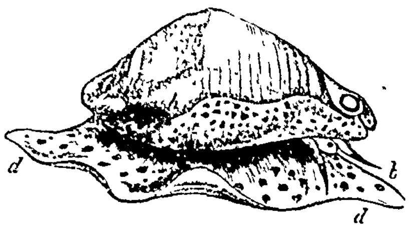

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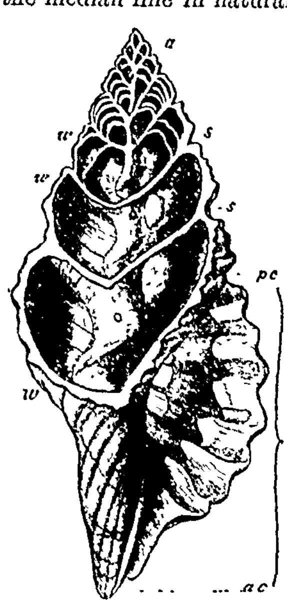

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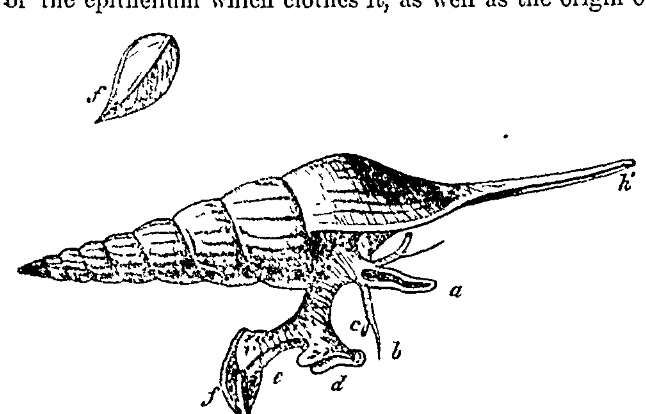

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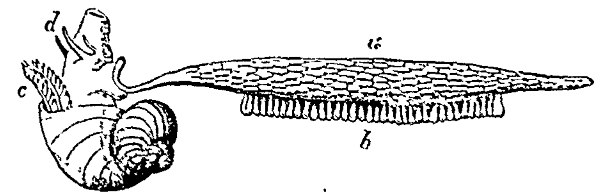

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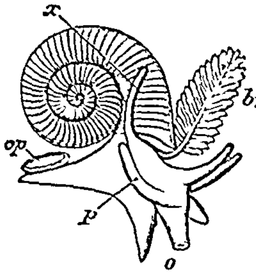

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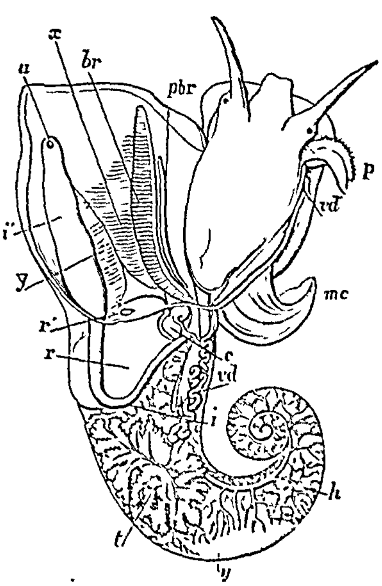

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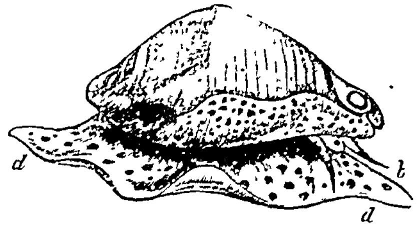

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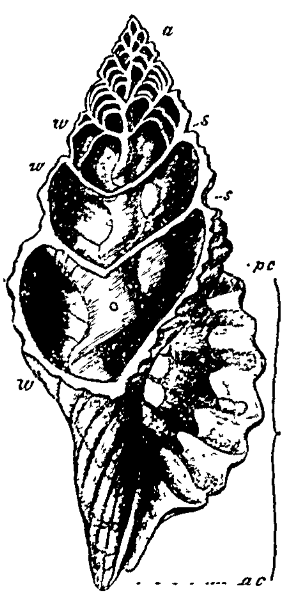

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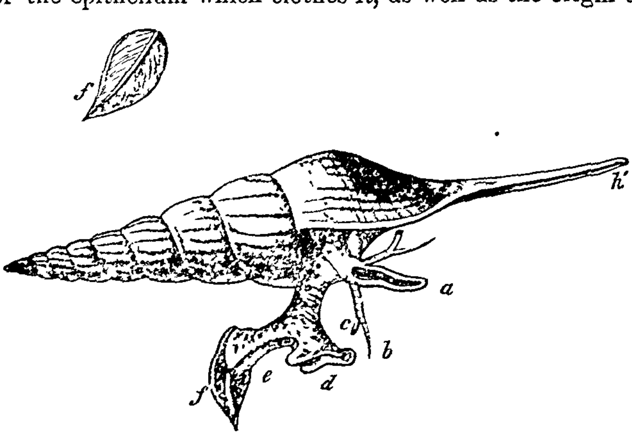

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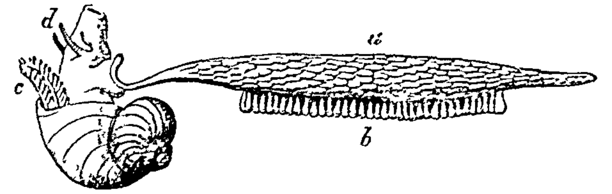

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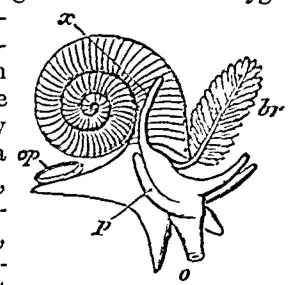

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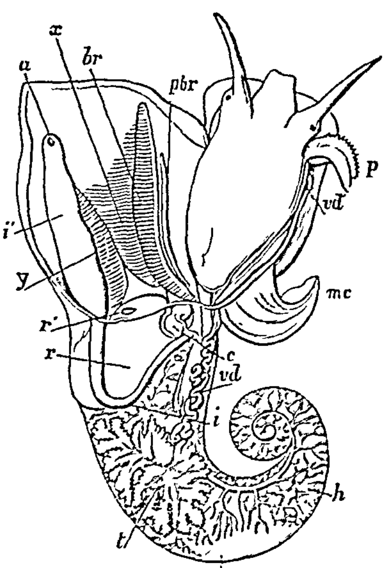

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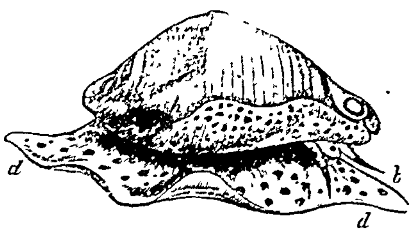

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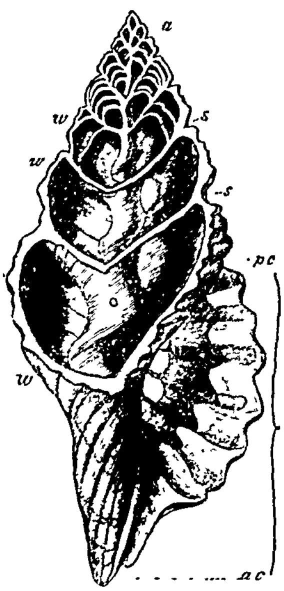

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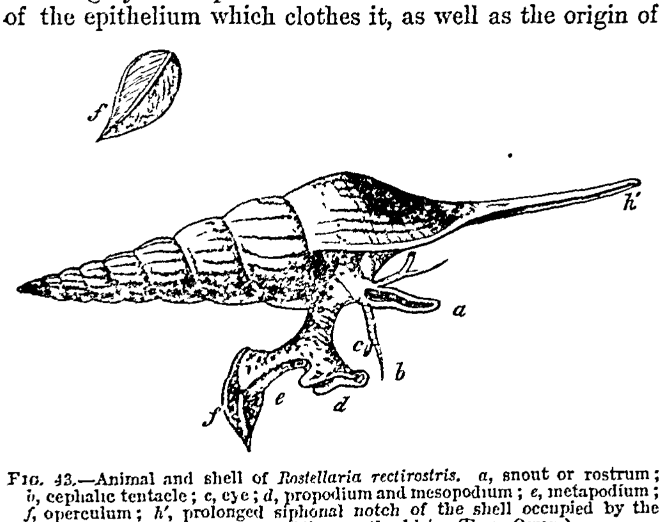

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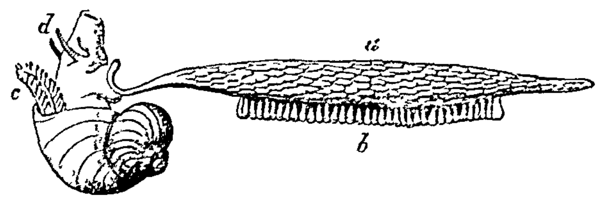

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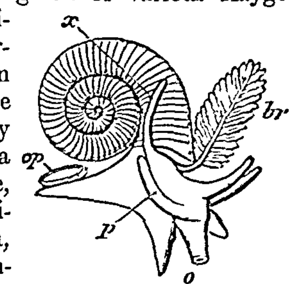

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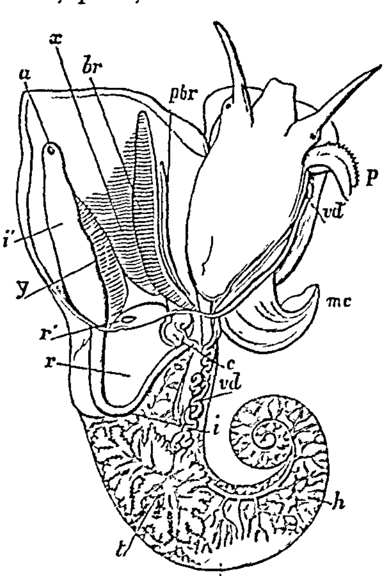

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termed, which is also the condition presented by the mouth-bearing region in nearly all other Gastropoda. One of the best examples of the introversible mouth-cylinder or proboscis which can be found is that of the Common Whelk and its immediate allies. In fig. 37 the proboscis is seen in an everted state; it is only so carried when feeding, being withdrawn when the animal is at rest. Probably its use is to enable the animal to introduce its rasping and licking apparatus into very narrow apertures for the purpose of feeding, *e.g.*, into a small hole bored in the shell of another Mollusc.

The foot of the Azygobranchia, unlike the simple muscular disc of the Isopleura and Zygobranchia, is very often divided into lobes, a fore, middle, and hind lobe (pro-, meso-, and meta-podium, see figs. 39 and 43). Very usually, but not universally, the meta-podium carries an operculum. The division of the foot into lobes is a simple case of that much greater elaboration or breaking up into processes and regions which it undergoes in the class Cephalopoda. Even among some Gastropoda (viz., the Opisthobranchia), we find the lobation of the foot still further carried out by the development of lateral lobes, the epipodia, whilst there are many Azygobranchia, on the other hand, in which the foot has a simple oblong form without any trace of lobes.

The development of the Azygobranchia from the egg has been followed in several examples, *e.g.*, Paludina, Purpura, Nassa, Vermetus, Neritina. As in other Molluscan groups, we find a wide variation in the early process of the formation of the first embryonic cells, and their arrangement as a *Diblastula dependent on the greater or less amount of* food-yelk which is present in the egg-cell when it commences its embryonic changes. In fig. 7, the early stages of *Paludina vivipara* are represented. There is but very little food-material in the egg of this Azygobranch, and consequently the Diblastula forms by invagination; the blastopore or orifice of invagination coincides with the anus, and never closes entirely. A well-marked Trochosphere is formed by the development of an equatorial ciliated band; and subsequently, by the disproportionate growth of the lower hemisphere, the Trochosphere becomes a Veliger. The primitive shell-sac or shell-gland is well marked at this stage, and the pharynx is seen as a new ingrowth (the stomodæum), about to fuse with and open into the primitively invaginated arch-enteron (fig. 7, F).

In other Azygobranchs (and such variations are representative for all Mollusca, and not characteristic only of Azygobranchia), we find that there is a very unequal division of the egg-cell at the commencement of embryonic development, as in Nassa (fig. 5). Consequently there is strictly speaking no invagination (emboly), but an overgrowth (epiboly) of the smaller cells to enclose the larger. The general features of this process and of the relation of the blastopore to mouth and anus have been explained above in treating of the development of Mollusca generally. In such cases the blastopore may entirely close, and both mouth and anus develop as new ingrowths (stomodæum and proctodæum), whilst, according to the observations of Bobretzky, the closed blastopore may coincide in position with the mouth in some instances (Nassa, &c.), instead of with the anus. But in these epibolic forms, just as in the embolic Paludina, the embryo proceeds to develop its ciliated band and shell-gland, passing through the earlier condition of a Trochosphere to that of the Veliger. In the veliger stage many Azygobranchia (Purpura, Nassa, &c.) exhibit, in the dorsal region behind the head, a contractile area of the body-wall. This acts as a larval heart, but ceases to pulsate after a time. Similar rhythmically contractile areas are found on the foot of the embryo Pulmonate Limax and on the yelk-sac (distended foot-surface) of the Cephalopod Loligo (see fig. 72**).

The history of the shell in the development of Azygobranchia (and other Gastropods) is important. Just as the primitive shell-sac aborts and gives place to a cap-like or boat-like shell, so in some cases (Marsenia, Krohn) has this first shell been observed to be shed, and a second shell of different shape is formed beneath it.

A detailed treatment of what is known of the histogenesis in relation to the cell-layers in these Mollusca would take us far beyond the limits of this article, which aims at exposing only the well-ascertained characteristic features of the Mollusca and the various subordinate groups. There is still a great deficiency in our knowledge of the development of the Gastropoda, as indeed of all classes of animals. The development of the gill (ctenidium) as well as of the renal organ, and details as to the process of torsion of the visceral hump, are still quite insufficiently known.

One further feature of the development of the Azygobranchia deserves special mention. Many Gastropoda deposit their eggs, after fertilization, enclosed in capsules; others, as Paludina, are viviparous; others, again, as the Zygobranchia, agree with the Lamellibranch Conchifera (the Bivalves) in having simple exits for the ova without glandular walls, and therefore discharge their eggs unenclosed in capsules freely into the sea-water; such unencapsuled eggs are merely enclosed each in its own delicate chorion. When egg-capsules are formed they are often of large size, have tough walls, and in each capsule are several eggs floating in a viscid fluid. In some cases all the eggs in a capsule develop; in other cases one egg only in a capsule (Neritina), or a small proportion (Purpura, Buccinum), advance in development; the rest are arrested either after the first process of cell-division (cleavage) or before that process. The arrested embryos or eggs are then swallowed and digested by those in the same capsule which have advanced in development. The details of this history require renewed study, our present knowledge of it being derived from the works of Koren and Danielssen, Carpenter and Claparède. In any case it is clearly the same process in essence as that of the formation of a vitellogenous gland from part of the primitive ovary, or of the feeding of an ovarian egg by the absorption of neighbouring potential eggs; but here the period at which the sacrifice of one egg to another takes place is somewhat late. What it is that determines the arrest of some eggs and the progressive development of others in the same capsule is at present unknown.

Section *b* (of the Azygobranchia).—*NATANTIA.*

Characters.—Azygobranchiate Streptoneura which have the form and texture of the body adapted to a free-swimming pelagic habit. They appear to be derived from holochlamydic forms of Reptant Azygobranchia. The foot takes the form of a swimming organ. The nervous system and sense-organs (eyes, otocysts, and osphradium) are highly developed. The odontophore also is remarkably developed, its admedian teeth being mobile, and it serves as an efficient organ for attacking other pelagic forms upon which the Natantia prey. The sexes are distinct as in all Streptoneura; and genital ducts and accessory glands and pouches are present as in all Azygobranchia. The Natantia exhibit a series of modifications of the form and proportions of the visceral mass and foot, leading from a condition readily comparable with that of a typical Azygobranch such as Rostellaria, with the three regions of the foot (pro-, meso-, and meta-podium) strongly marked, and a coiled visceral hump of the usual proportions, up to a condition in which the whole body is of a tapering cylindrical shape, the foot a plate-like vertical fin, and the visceral hump almost completely atrophied. Three steps of this modification may be distinguished as three sub-orders, the *Atlantacea*, the *Carinariacea*, and the *Pterotracheacea.*

Sub-order 1.—*Atlantacea.*

Characters.—Natantia with a large spirally-wound visceral hump, covered by a hyaline spiral shell; mantle-skirt large, overhanging a well-developed sub-pallial branchial chamber as in Azygobranchia, to the wall of which is attached the branchial ctenidium; foot well developed, divisible into a mobile propodium, a mesopodium on which is formed a sucker, and a metapodium which, when the animal is expanded, extends backwards beyond the shell and visceral

termed, which is also the condition presented by the mouth-bearing region in nearly all other Gastropoda. One of the best examples of the introversible mouth-cylinder or proboscis which can be found is that of the Common Whelk and its immediate allies. In fig. 37 the proboscis is seen in an everted state; it is only so carried when feeding, being withdrawn when the animal is at rest. Probably its use is to enable the animal to introduce its rasping and licking apparatus into very narrow apertures for the purpose of feeding, *e.g.*, into a small hole bored in the shell of another Mollusc.

The foot of the Azygobranchia, unlike the simple muscular disc of the Isopleura and Zygobranchia, is very often divided into lobes, a fore, middle, and hind lobe (pro-, meso-, and meta-podium, see figs. 39 and 43). Very usually, but not universally, the meta-podium carries an operculum. The division of the foot into lobes is a simple case of that much greater elaboration or breaking up into processes and regions which it undergoes in the class Cephalopoda. Even among some Gastropoda (viz., the Opisthobranchia), we find the lobation of the foot still further carried out by the development of lateral lobes, the epipodia, whilst there are many Azygobranchia, on the other hand, in which the foot has a simple oblong form without any trace of lobes.

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Section *b* (of the Azygobranchia).—*NATANTIA.*

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Branch *b*.—*EUTHYNEURA* (Spengel, 1881).

Characters. — Gastropoda Anisopleura in which the visceral loop (the conterminous visceral nerves) does not share in the torsion of the visceral hump, but, being sunk entirely below the body-wall, remains straight and untwisted. Although the anus is not brought so far forward

FIG. 52.—*Bulla textilum* (Chemnitz), as seen crawling. *a*, oral hood (compare with Tethys, fig. 62, B), possibly a continuation of the epipodia; *b*, *b′*, cephalic tentacles. (From Owen.)

by the visceral torsion as in the Streptoneura, and may even by *secondary* growth assume a posterior median position, yet, as fully developed, an asymmetry has resulted as in the Azygobranchia, only the original right renal organ, right *ctenidium* (*if any*), right osphradium, right side of the heart, and right genital ducts being retained. All the Euthyneura are hermaphrodite. The lingual ribbon has very usually numerous fine denticles undifferentiated into series in each row. The shell is light and little calcified; often it is not developed in the adult, though present in the embryo. An operculum, often found in the embryo, is never present in the adult (except in Tornatella, fig. 53). Many Euthyneura show a tendency to, or a complete accomplishment of, the suppression of the mantle-skirt as well as of the shell, also of the ctenidium, and acquire at the same time a more or less cylindrical (slug-like) form of body.

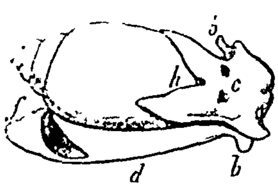

FIG. 53.—Tornatella. *h*, shell; *b*, oral hood; *d*, foot; *f*, operculum.

The Euthyneura comprise two orders, the Opisthobranchia and the Pulmonata.

Order 1.—Opisthobranchia.

Marine Euthyneura the more archaic forms of which have a relatively large foot and a small visceral hump, from the base of which projects on the right side a short mantle-skirt. The anus is placed in such forms far back

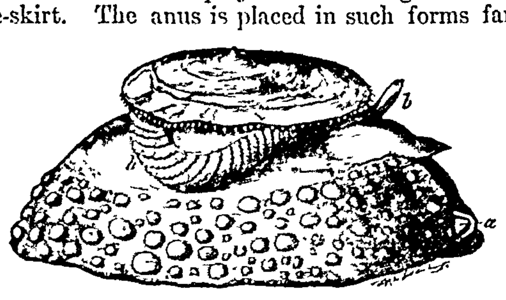

FIG. 54.—*Umbrella mediterranea.* *a*, mouth; *b*, cephalic tentacle; *h*, gill (ctenidium). The free edge of the mantle is seen just below the margin of the shell (compare with Aplysia, fig. 63) (From Owen.)

beyond the mantle-skirt. In front of the anus, and only partially covered by the mantle-skirt, is the ctenidium with its free end turned backwards. The heart lies in front of, instead of to the side of, the attachment of the ctenidium, —hence Opisthobranchia as opposed to "Prosobranchia," which correspond to the Streptoneura. A shell is possessed in the adult state by but few Opisthobranchia, but all pass through a veliger larval stage with a nautiloid shell (fig. 60). Many Opisthobranchia have by a process of atrophy lost the typical ctenidium and the mantle-skirt, and have developed other organs in their place. As in some Azygobranchia, the free margin of the mantle-skirt is frequently reflected over the shell when a shell exists; and, as in some Azygobranchia, broad lateral outgrowths of the foot (epipodia) are often developed, which, as does *not* occur in Azygobranchia, may be thrown over the shell or naked dorsal surface of the body.

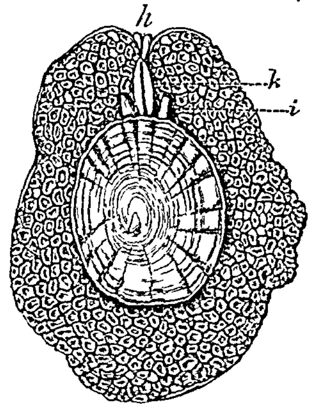

FIG. 55.—*Umbrella mediterranea*, seen from above. *h*, mouth; *i*, cephalic tentacles; *k*, penis sheath. (After Keferstein.)

The variety of special developments of structure accompanying the atrophy of typical organs in the Opisthobranchia and general degeneration of organization is very great, and renders their classification difficult. Two sections of the order may be distinguished, according as the typical Molluscan mantle-skirt (limbus pallialis) is or is not atrophied, and within each section certain sub-orders.

Section *a*.—*PALLIATA* (= *Tectibranchiata*, Woodward)—the typical Molluscan mantle-skirt or pallium retained.

Sub-order 1.—*Ctenidiobranchia.*

Characters.—Palliata in which the ctenidium is retained as the branchial organ; with rare exceptions a delicate shell, which may be very small or completely enclosed by the reflected margin of the mantle; epipodia (lateral outgrowths of the foot) frequently present.

Family 1.—*Tornatellidæ.*
Genera: *Tornatella*, Lam. (fig. 53); *Cinulia*, Gray, &c.
Family 2.—*Bullidæ.*
Genera: *Bulla*, Lam. (fig. 52); *Acera*, Muller; *Scaphander*, Montf.; *Bullæa*, Lam.; *Doridium*, Meckel; *Gastropteron*, Meckel, &c.
Family 3.—*Aplysiidæ.*
Genera: *Aplysia*, Gmelin (the Sea-Hare) (figs. 20, 56, &c.); *Dolobella*, Lam.; *Lobiger*, Krohn, &c.
Family 4.—*Pleurobranchidæ.*
Genera: *Pleurobranchus*, Cuvier; *Umbrella*, Chemnitz (figs. 54, 55); *Runcina*, Forbes, &c.

Sub-order 2.—*Phyllidiobranchia.*

Characters.—Palliata in which the ctenidia have atrophied; much as in Patellidæ among the Zygobranchiate Streptoneura their place is taken by laterally-placed lamellæ, developed from the inner surface of the bilaterally-disposed mantle-skirt in two lateral rows.

Family 5.—*Phyllidiadæ.*
Genera: *Phyllidia*, Cuiver; *Pleurophyllidia*, Meck. (fig. 57).

Section *b*.—*NON-PALLIATA.*

Characters.—The typical Molluscan mantle-skirt is atrophied in the adult. No shell is present in the adult, though the dorsal integument may be strengthened by calcareous spicules (Doris). The otocysts are not sessile on the pedal ganglia as in other Gastropods, but, as in the Natantia Azygobranchia, lie close to the cerebral ganglia. In one sub-order (Pygobranchia) the typical ctenidium appears to be retained in a modified form; in the others special developments of the body-wall take its place, or no special respiratory processes exist at all. The general form of the body is slug-like, the foot and visceral hump being coextensive, and a secondary bilateral symmetry is asserted by the usually median (sometimes right-sided) dorsal position of the anus on the hinder part of the body.

Sub-order 1.—*Pygobranchia.*

Characters.—The ctenidium assumes the form of a circlet of pinnate processes surrounding the median dorsal anus; a strongly-marked epipodial fold may occur all round the foot and simulate a mantle-skirt (see fig. 62, C, Doris); papillæ or "cerata" of the dorsal integument may occur as well as the true ctenidium (fig. 61).

Family 6.—*Dorididæ.*
Genera: *Doris*, L; *Goniodoris*, Forbes; *Triopa*, Johnst.; *Ægirus*, Loven; *Thecacera*, Fleming; *Polycera*, Cuvier; *Idalia*, Leuckart; *Ancula*, Loven; *Ceratosoma*, Adams; *Onchidoris*, Blainv.

Branch *b.—EUTHYNEURA* (Spengel, 1881).

Characters. — Gastropoda Anisopleura in which the visceral loop (the conterminous visceral nerves) does not share in the torsion of the visceral hump, but, being sunk entirely below the body-wall, remains straight and untwisted. Although the anus is not brought so far forward

FIG. 52.—*Bulla textilum* (Chemnitz), as seen crawling. *á*, oral hood (compare with Tethys, fig. 62, B), possibly a continuation of the epipodia; *b*, *b′*, cephalic tentacles. (From Owen.)

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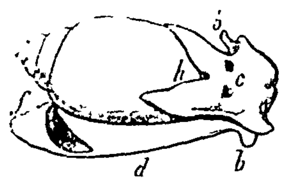

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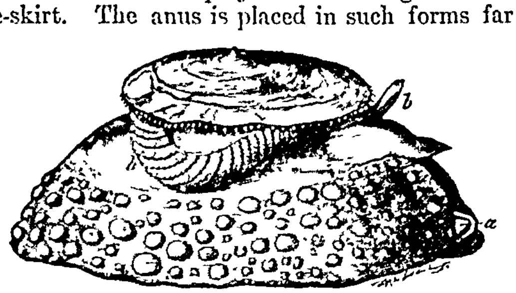

FIG. 54.—*Umbrella mediterranea.* *a*, mouth; *b*, cephalic tentacle; *h*, gill (ctenidium). The free edge of the mantle is seen just below the margin of the shell (compare with Aplysia, fig. 63) (From Owen.)

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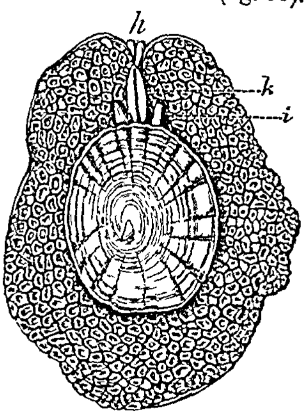

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Genera: *Aplysia*, Gmelin (the Sea-Hare) (figs. 20, 56, &c.); *Dolobella*, Lam.; *Lobiger*, Krohn, &c.

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Characters.—Palliata in which the ctenidia have atrophied; much as in Patellidæ among the Zygobranchiate Streptoneura their place is taken by laterally-placed lamellæ, developed from the inner surface of the bilaterally-disposed mantle-skirt in two lateral rows.

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Characters.—The typical Molluscan mantle-skirt is atrophied in the adult. No shell is present in the adult, though the dorsal integument may be strengthened by calcareous spicules (Doris). The otocysts are not sessile on the pedal ganglia as in other Gastropods, but, as in the Natantia Azygobranchia, lie close to the cerebral ganglia. In one sub-order (Pygobranchia) the typical ctenidium appears to be retained in a modified form; in the others special developments of the body-wall take its place, or no special respiratory processes exist at all. The general form of the body is slug-like, the foot and visceral hump being coextensive, and a secondary bilateral symmetry is asserted by the usually median (sometimes right-sided) dorsal position of the anus on the hinder part of the body.

Sub-order 1.—*Pygobranchia.*

Characters.—The ctenidium assumes the form of a circlet of pinnate processes surrounding the median dorsal anus; a strongly-marked epipodial fold may occur all round the foot and simulate a mantle-skirt (see fig. 62, C, Doris); papillæ or "cerata" of the dorsal integument may occur as well as the true ctenidium (fig. 61).

Family 6.—*Dorididæ.*

Genera: *Doris*, L.; *Goniodoris*, Forbes; *Triopa*, Johnst.; *Ægirus*, Loven; *Thecacera*, Fleming; *Polycera*, Cuvier; *Idalia*, Leuckart; *Ancula*, Loven; *Ceratosoma*, Adams; *Onchidoris*, Blainv.

63 projecting from the branchial sub-pallial space. The relation of the delicate shell to the mantle is peculiar, since it occupies an oval area upon the visceral hump, the extent of which is indicated in fig. 56, C, but may be better understood by a glance at the figures of the allied genus Umbrella (figs. 54, 55), in which the margin of the mantle-skirt coincides, just as it does in the Limpet, with the margin of the shell. But in Aplysia the mantle is reflected over the edge of the shell, and grows over its upper surface so as to completely enclose it, excepting at the small central area *s* where the naked shell is exposed. This enclosure of the shell is a permanent development of the arrangement seen in many Streptoneura (*e.g.*, Pyrula, Ovulum, see figs. 38 and 41), where the border of the mantle can be, and usually is, drawn over the shell, though it is withdrawn (as it cannot be in Aplysia) when they are irritated. From the fact that Aplysia commences its life as a free-swimming Veliger with a nautiloid shell not enclosed in any way by the border of the mantle, it is clear that the enclosure of the shell in the adult is a secondary process. Accordingly, the shell of Aplysia must not be confounded with a primitive shell in its shell-sac, such as we find realized in the shells of Chiton and in the plugs which form in the remarkable transitory "shell-sac" or "shell-gland" of Molluscan embryos

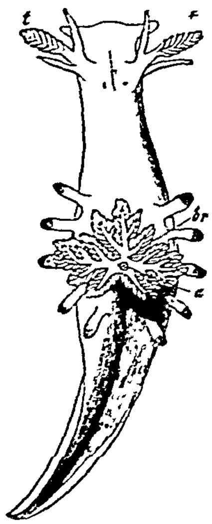

FIG. 61.—*Polycera cristata*, one of the Pygobranchiate Opisthobranchs (dorsal view). *a*, anus; *br*, the ctenidium peculiarly modified so as to encircle the anus; *t*, cephalic tentacles. External to the branchial ctenidium are seen ten club-like processes of the dorsal wall, these are the "cerata" which are characteristically developed in another sub-order of Opisthobranchs, the Ceratonota (see fig. 62, A). (From Gegenbaur, after Alder and Hancock.)

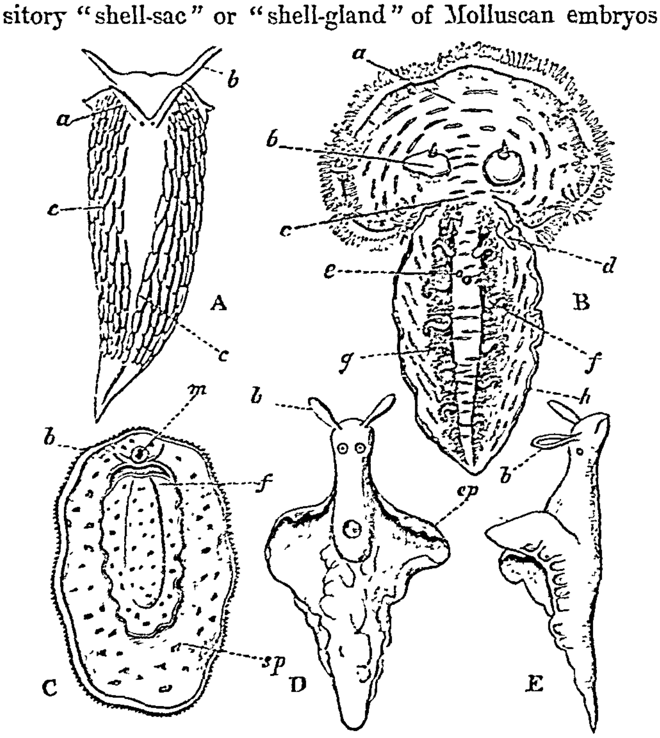

FIG. 62.
A. *Eolis papillosa* (Lin.), dorsal view. *a*, *b*, posterior and anterior cephalic tentacles; *c*, the dorsal "cerata" (hence Ceratobranchia).
B. *Tethys leporina*, dorsal view. *a*, the cephalic hood; *b*, cephalic tentacles; *c*, neck; *d*, genital pore; *e*, anus; *f*, large cerata; *g*, smaller cerata; *h*, margin of the foot.
C. *Doris (Actinocyclus) tuberculatus* (Cuv.), seen from the pedal surface. *m*, mouth; *b*, margin of the head; *f*, sole of the foot; *sp*, the mantle-like epipodium.
D, E. Dorsal and lateral view of *Elysia (Actæon) viridis*. *ep*, epipodial outgrowths. (After Keferstein.)

(see figs. 7, 68, and 72***). Aplysia, like other Mollusca, develops a primitive shell-sac in its trochosphere stage of development (fig. 68), which disappears and is succeeded by a nautiloid shell (fig. 60). This forms the nucleus of the adult shell, and, as the animal grows, becomes enclosed by a reflexion of the mantle-skirt. In reference to the possible comparison of the enclosed shell of Aplysia and its allies with those of some Slugs and of Cuttle-fishes, the reader is referred to the paragraphs dealing especially with those Molluscs. When the shell of an Aplysia enclosed in its mantle is pushed well to the left, the sub-pallial space is fully exposed as in fig. 63, and the various apertures of the body are seen. Posteriorly we have the anus, in front of this the lobate gill-plume, between the two (hence corresponding in position to that of the Azygobranchia) we have the aperture of the renal organ. In front, near the anterior attachment of the gill-plume, is the osphradium (olfactory organ) discovered by Spengel, yellowish in colour, in the typical position, and overlying an olfactory ganglion with typical nerve-connexion (see fig. 20). To the right of Spengel's osphradium is the opening of a peculiar gland which has, when dissected out, the form of a bunch of grapes; its secretion is said to be poisonous. On the under side of the free edge of the mantle are situated the numerous small cutaneous glands which, in the large *Aplysia camelus* (not in other species), form the purple secretion which was known to the ancients. In front of the osphradium is the single genital pore, the aperture of the common or hermaphrodite duct. From this point there stretches forward to the right side of the head a groove—the spermatic groove—down which the spermatic fluid passes. In other Euthyneura this groove may close up and form a canal. At its termination by the side of the head is the muscular introverted penis. In the hinder part of the foot (not shown in any of the diagrams) is the opening of a large mucous-forming gland very often found in the Molluscan foot.

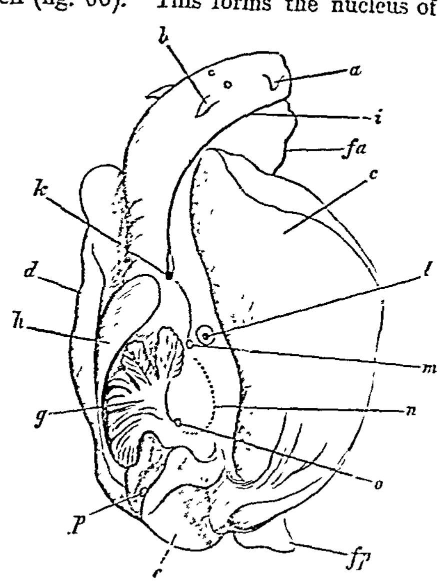

FIG. 63.—*Aplysia leporina* (*camelus*, Cuv.), with epipodia and mantle reflected away from the mid-line. *a*, anterior cephalic tentacle; *b*, posterior do.; between *a* and *b*, the eyes; *c*, right epipodium; *d*, left epipodium; *e*, hinder part of visceral hump; *fp*, posterior extremity of the foot; *fa*, anterior part of the foot underlying the head; *g*, the ctenidium (branchial plume); *h*, the mantle-skirt tightly spread over the horny shell and pushed with it towards the left side; *i*, the spermatic groove; *k*, the common genital pore (male and female); *l*, orifice of the grape-shaped (supposed poisonous) gland; *m*, the osphradium (olfactory organ of Spengel); *n*, outline of part of the renal sac (nephridium) below the surface; *o*, external aperture of the nephridium; *p*, anus. (Original.)

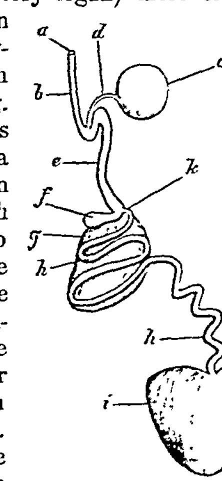

FIG. 64.—Gonad, and accessory glands and ducts of Aplysia. *i*, ovo-testis; *h*, hermaphrodite duct; *g*, albuminiparous gland; *f*, vesicula seminalis; *k*, opening of the albuminiparous gland into the hermaphrodite duct; *e*, hermaphrodite duct (uterine portion); *b*, vaginal portion of the uterine duct; *c*, spermatheca; *d*, its duct; *a*, genital pore. (Original.)

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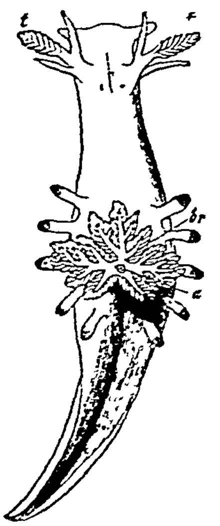

FIG. 61.—*Polycera cristata*, one of the Pygobranchiate Opisthobranchs (dorsal view). *a*, anus; *br*, the ctenidium peculiarly modified so as to encircle the anus; *t*, cephalic tentacles. External to the branchial ctenidium are seen ten club-like processes of the dorsal wall, these are the "cerata" which are characteristically developed in another sub-order of Opisthobranchs, the Ceratonota (see fig. 62, A). (From Gegenbaur, after Alder and Hancock.)

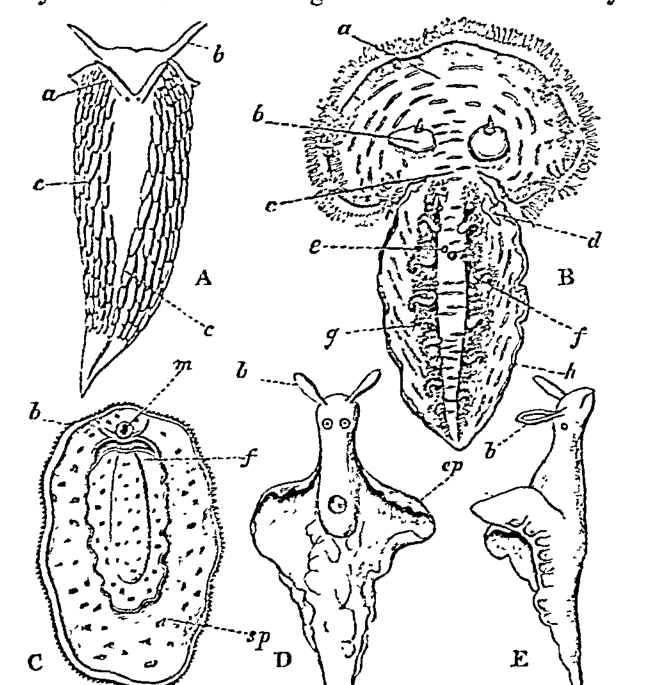

FIG. 62.
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B. *Tethys leporina*, dorsal view. *a*, the cephalic hood; *b*, cephalic tentacles; *c*, neck; *d*, genital pore; *e*, anus; *f*, large cerata; *g*, smaller cerata; *h*, margin of the foot.
C. *Doris (Actinocyclus) tuberculatus* (Cuv.), seen from the pedal surface. *m*, mouth; *b*, margin of the head; *f*, sole of the foot; *ep*, the mantle-like epipodium.
D, E. Dorsal and lateral view of *Elysia (Actæon) viridis*. *ep*, epipodial outgrowths. (After Keferstein.)

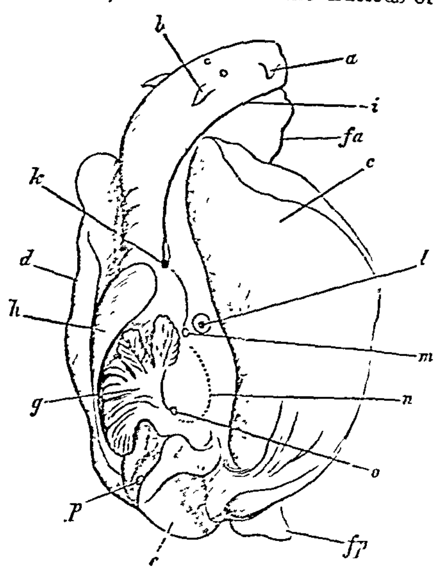

FIG. 63.—*Aplysia leporina* (*camelus*, Cuv.), with epipodia and mantle reflected away from the mid-line. *a*, anterior cephalic tentacle; *b*, posterior do.; between *a* and *b*, the eyes; *c*, right epipodium; *d*, left epipodium; *e*, hinder part of visceral hump; *fp*, posterior extremity of the foot; *fa*, anterior part of the foot underlying the head; *g*, the ctenidium (branchial plume); *h*, the mantle-skirt tightly spread over the horny shell and pushed with it towards the left side; *i*, the spermatic groove; *k*, the common genital pore (male and female); *l*, orifice of the grape-shaped (supposed poisonous) gland; *m*, the osphradium (olfactory organ of Spengel); *n*, outline of part of the renal sac (nephridium) below the surface; *o*, external aperture of the nephridium; *p*, anus. (Original.)

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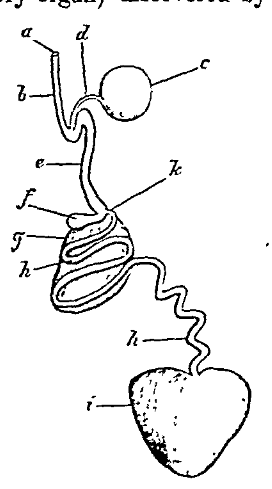

FIG. 64.—Gonad, and accessory glands and ducts of Aplysia. *i*, ovo-testis; *h*, hermaphrodite duct; *g*, albuminiparous gland; *f*, vesicula seminalis; *l*, opening of the albuminiparous gland into the hermaphrodite duct; *e*, hermaphrodite duct (uterine portion); *b*, vaginal portion of the uterine duct; *c*, spermatheca; *d*, its duct; *a*, genital pore. (Original.)

Aplysia hybrida of the English coast), placed at its extreme limit, representing both the right and left visceral ganglia and the third or abdominal ganglion, which are so often separately present. The diagram (fig. 20) shows the nerve connecting this abdomino-visceral ganglion with the olfactory ganglion of Spengel. It is also seen to be connected with a more remote ganglion—the genital. Such special irregularities in the development of ganglia upon the visceral loop, and on one or more of the main nerves connected with it, are, as the figures of Molluscan nervous systems given in this article show, very frequent. Our figure of the nervous system of Aplysia does not give the small pair of buccal ganglia which are, as in all Glossophorous Molluscs, present upon the nerves passing from the cerebral region to the odontophore.

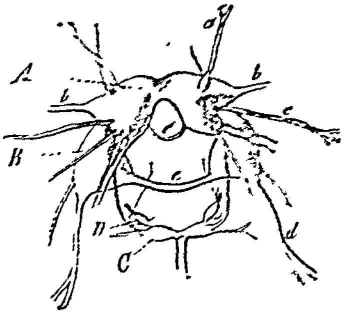

FIG. 67.—Central nervous system of Fiona (one of the Ceratonotous Opisthobranchs), showing a tendency to fusion of the great ganglia. *A*, cerebral, pleural, and visceral ganglia united; *B*, pedal ganglion; *C*, buccal ganglion; *D*, œsophageal ganglion connected with the buccal; *a*, nerve to superior cephalic tentacle; *b*, nerves to inferior cephalic tentacles; *c*, nerve to generative organs; *d*, pedal nerve; *e*, pedal commissure; *e'*, visceral loop or commissure (?). (From Gegenbaur, after Bergh.)

For a comparison of various Opisthobranchs, Aplysia will be found to present a convenient starting-point. It is one of the more typical Opisthobranchs, that is to say, it belongs to the section Palliata, but other members of the Palliata, namely, Bulla and Tornatella (figs. 52 and 53), are less abnormal than Aplysia in regard to their shells and the form of the visceral hump. They have naked spirally-twisted shells which may be concealed from view in the living animal by the expansion and reflexion of the epipodia,

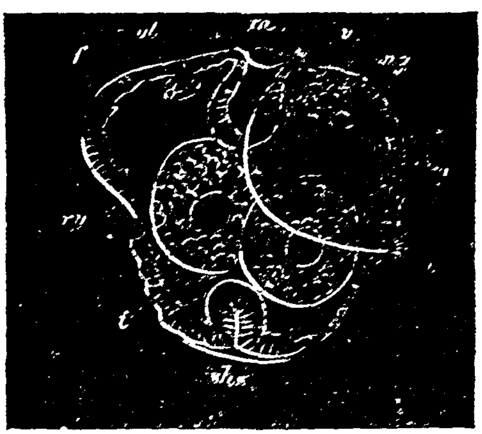

FIG. 68.—Young veliger larva of an Opisthobranch (Pleuro-branchidium). *m*, mouth; *v*, ciliated band marking off the velum; *ng*, cerebral ganglion developing from epiblast, within the velar area; *ot*, otocyst also developing from epiblast; *f*, foot; *i*, intestine; *ry*, residual nutritive yelk; *sh*, primitive shell-sac or shell-gland. (From Lankester.)

but are not enclosed by the mantle, whilst Tornatella is remarkable amongst all Euthyneura for possessing an operculum like that of so many Streptoneura.

The great development of the epipodia seen in Aplysia is usual in Palliate Opisthobranchs; it occurs also in Elysia (fig. 62, D) among Non-Palliata; in Doris it seems probable that the mantle-like fold overhanging the foot is to be interpreted as epipodium, the mantle-skirt being altogether absent, as shown by the naked position of the gills and anus on the dorsal surface (figs. 61 and 62, C). The whole surface of the body becomes greatly modified in those Non-Palliate forms which have lost, not only the mantle-skirt and the shell, but also the ctenidium. Many of these (Ceratonota) have peculiar processes developed on the dorsal surface (fig. 62, A, B), or retain purely negative characters (fig. 62, D). The chief modification of internal organization presented by these forms, as compared with Aplysia, is found in the condition of the alimentary canal. The liver is no longer a compact organ opening by a pair of ducts into the median digestive tract, but we find very numerous hepatic diverticula on a shortened axial tract (fig. 66). These diverticula extend usually one into each of the dorsal papillæ or "cerata" when these are present. They are not merely digestive glands, but are sufficiently wide to act as receptacles of food, and in them the digestion of food proceeds just as in the axial portion of the canal. A precisely similar modification of the liver or great digestive gland is found in the Scorpions, where the axial portion of the digestive canal is short and straight, and the lateral ducts sufficiently wide to admit food into the ramifications of the gland there to be digested; whilst in the Spiders the gland is reduced to a series of simple cæca.

The typical character is retained by the heart, pericardium, and the communicating nephridium or renal organ in all Opisthobranchs. An interesting example of this is furnished by the fish-like transparent Phyllirhoë (fig. 58), in which it is possible most satisfactorily to study in the living animal, by means of the microscope, the course of the blood-stream, and also the reno-pericardial communication. With reference to the existence of pores placing the vascular system in open communication with the surrounding water, see the paragraph as to Mollusca generally. In a form closely allied to Aplysia (Pleurobranchus) such a pore leading outwards from the branchial vein has been precisely described by Lacaze Duthiers. No such pore has been detected in Aplysia. In many of the Non-Palliate Opisthobranchs the nervous system presents a concentration of the ganglia (fig. 67), contrasting greatly with what we have seen in Aplysia. Not only are the pleural ganglia fused to the cerebral, but also the visceral to these (see in further illustration the condition attained by the Pulmonate Limnæus, fig. 22), and the visceral loop is astonishingly short and insignificant (fig. 67, *e'*). That the parts are rightly thus identified is probable from Spengel's observation of the osphradium and its nerve-supply in these forms; the nerve to that organ, which is placed somewhat anteriorly—on the dorsal surface—being given off from the hinder part (visceral) of the right compound ganglion—the fellow to that marked A in fig. 67. The Ceratonotous Opisthobranchs, amongst other specialities of structure, are stated to possess (in some cases at any rate) apertures at the apices of the "cerata" or dorsal papillæ, which lead from the exterior into the hepatic cæca. This requires confirmation. Some amongst them (Tergipes, Eolis) are also remarkable for possessing peculiarly modified epidermic cells placed in sacs at the apices of these same papillæ, which resemble the "thread-cells" of the Planarian Flatworms and of the Cœlentera. The existence of these thread-cells is sufficiently remarkable, seeing that the Non-Palliate Opisthobranchs resemble in general form and habit the Planarian worms, many of which also possess thread-cells. But it is not conceivable that their presence is an indication of genetic affinity between the two groups, rather they are instances of homoplasy. The development of many Opisthobranchia has been examined—*e.g.*, Aplysia, Pleurobranchidium, Elysia, Polycera, Doris, Tergipes. All pass through trochosphere and veliger stages, and in all a nautiloid or boat-like shell is developed, preceded by a well-marked "shell-gland" (see figs. 60 and 68). The transition from the free-swimming veliger larva with its nautiloid shell (fig. 60) to the adult form has not been properly observed, and many interesting points as to the true nature of folds (whether epipodia or mantle or velum) have yet to be cleared up by a knowledge of such development in forms like Tethys, Doris, Phyllidia, &c.

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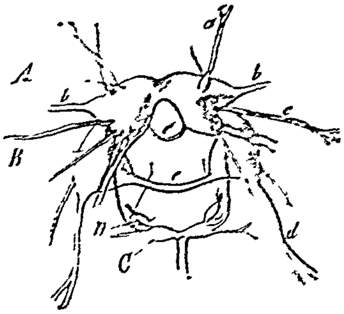

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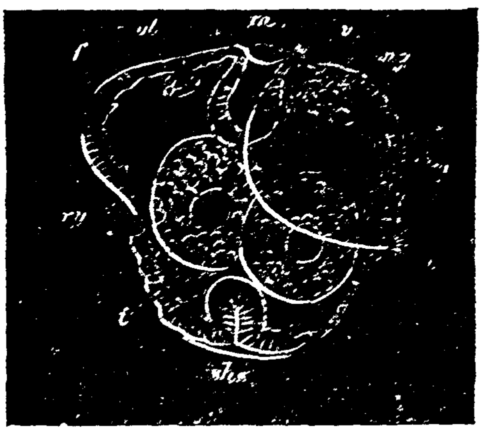

Fig. 68.—Young veliger larva of an Opisthobranch (Pleurobranchidium). *m*, mouth; *v*, ciliated band marking off the velum; *cg*, cerebral ganglion developing from epiblast, within the velar area; *ot*, otocyst also developing from epiblast; *f*, foot; *i*, intestine; *ry*, residual nutritive yolk; *sh*, primitive shell-sac or shell-gland. (From Lankester.)

but are not enclosed by the mantle, whilst Tornatella is remarkable amongst all Euthyneura for possessing an operculum like that of so many Streptoneura.

The great development of the epipodia seen in Aplysia is usual in Palliate Opisthobranchs; it occurs also in Elysia (fig. 62, D) among Non-Palliata; in Doris it seems probable that the mantle-like fold overhanging the foot is to be interpreted as epipodium, the mantle-skirt being altogether absent, as shown by the naked position of the gills and anus on the dorsal surface (figs. 61 and 62, C). The whole surface of the body becomes greatly modified in those Non-Palliate forms which have lost, not only the mantle-skirt and the shell, but also the ctenidium. Many of these (Ceratonota) have peculiar processes developed on the dorsal surface (fig. 62, A, B), or retain purely negative characters (fig. 62, D). The chief modification of internal organization presented by these forms, as compared with Aplysia, is found in the condition of the alimentary canal. The liver is no longer a compact organ opening by a pair of ducts into the median digestive tract, but we find very numerous hepatic diverticula on a shortened axial tract (fig. 66). These diverticula extend usually one into each of the dorsal papillæ or "cerata" when these are present. They are not merely digestive glands, but are sufficiently wide to act as receptacles of food, and in them the digestion of food proceeds just as in the axial portion of the canal. A precisely similar modification of the liver or great digestive gland is found in the Scorpions, where the axial portion of the digestive canal is short and straight, and the lateral ducts sufficiently wide to admit food into the ramifications of the gland there to be digested, whilst in the Spiders the gland is reduced to a series of simple cæca.

The typical character is retained by the heart, pericardium, and the communicating nephridium or renal organ in all Opisthobranchs. An interesting example of this is furnished by the fish-like transparent Phyllirhoe (fig. 58), in which it is possible most satisfactorily to study in the living animal, by means of the microscope, the course of the blood-stream, and also the reno-pericardial communication. With reference to the existence of pores placing the vascular system in open communication with the surrounding water, see the paragraph as to Mollusca generally. In a form closely allied to Aplysia (Pleurobranchus) such a pore leading outwards from the branchial vein has been precisely described by Lacaze Duthiers. No such pore has been detected in Aplysia. In many of the Non-Palliate Opisthobranchs the nervous system presents a concentration of the ganglia (fig. 67), contrasting greatly with what we have seen in Aplysia. Not only are the pleural ganglia fused to the cerebral, but also the visceral to these (see in further illustration the condition attained by the Pulmonate Limnæus, fig. 22), and the visceral loop is astonishingly short and insignificant (fig. 67, *e′*). That the parts are rightly thus identified is probable from Spengel's observation of the osphradium and its nerve-supply in these forms; the nerve to that organ, which is placed somewhat anteriorly—on the dorsal surface—being given off from the hinder part (visceral) of the right compound ganglion—the fellow to that marked A in fig. 67. The Ceratonotous Opisthobranchs, amongst other specialities of structure, are stated to possess (in some cases at any rate) apertures at the apices of the "cerata" or dorsal papillæ, which lead from the exterior into the hepatic cæca. This requires confirmation. Some amongst them (Tergipes, Eolis) are also remarkable for possessing peculiarly modified epidermic cells placed in sacs at the apices of these same papillæ, which resemble the "thread-cells" of the Planarian Flatworms and of the Cœlentera. The existence of these thread-cells is sufficiently remarkable, seeing that the Non-Palliate Opisthobranchs resemble in general form and habit the Planarian worms, many of which also possess thread-cells. But it is not conceivable that their presence is an indication of genetic affinity between the two groups, rather they are instances of homoplasy. The development of many Opisthobranchia has been examined—*e.g.*, Aplysia, Pleurobranchidium, Elysia, Polycera, Doris, Tergipes. All pass through trochosphere and veliger stages, and in all a nautiloid or boat-like shell is developed, preceded by a well-marked "shell-gland" (see figs. 60 and 68). The transition from the free-swimming veliger larva with its nautiloid shell (fig. 60) to the adult form has not been properly observed, and many interesting points as to the true nature of folds (whether epipodia or mantle or velum) have yet to be cleared up by a knowledge of such development in forms like Tethys, Doris, Phyllidia, &c.

The same general range of body-form is shown in Pulmonata as in the Natant Azygobranchia and in the Opisthobranchia; at one extreme we have Snails with coiled visceral hump, at the other cylindrical or flattened Slugs (see fig. 69). Limpet-like forms are also found (fig. 71, Ancylus). The foot is always simple, with its flat crawling surface extending from end to end, but in the embryo Limnæus (fig. 4, H) it shows a bilobed character, which leads on to the condition characteristic of Pteropoda.

FIG. 71.—*Ancylus fluviatilis*, a patelliform aquatic Pulmonate.

The adaptation of the Pulmonata to terrestrial life has entailed little modification of the internal organization. The vascular system appears to be more complete in them than in other Gastropoda, fine vessels and even capillaries being present in place of lacunæ, in which arteries and veins find their meeting-point. The subject has not, however, been investigated by the proper methods of recent histology, and our knowledge of it, as of the vascular system of Molluscs generally, is most unsatisfactory. In one genus (Planorbis) the plasma of the blood is coloured red by hæmoglobin, this being the only instance of the presence of this body in the blood of Glossophorous Mollusca, though it occurs in corpuscles in the blood of the bivalves Arca and Solen (Lankester, **31**).

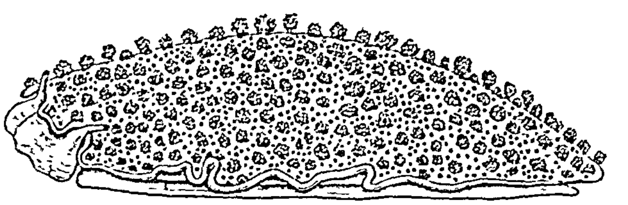

FIG. 72.—*Peronia Tongæ*, a littoral Pulmonate, found on the shores of the Indian and Pacific Oceans (Mauritius, Japan).

The generative apparatus of the Snail (Helix) may serve as an example of the hermaphrodite apparatus common to the Pulmonata and Opisthobranchia (fig. 72*). From the ovo-testis, which lies near the apex of the visceral coil, a common hermaphrodite duct *v.e* proceeds, which receives the duct of the compact white albuminiparous gland *E.d.*, and then becomes much enlarged, the additional width being due to the development of glandular folds, which are regarded as forming a uterus *u*. Where these folds cease the common duct splits into two portions, a male and a female. The male duct *v.d* becomes fleshy and muscular near its termination at the genital pore, forming the penis *p*. Attached to it is a diverticulum *fl.*, in which the spermatozoa which have descended from the ovo-testis are stored and modelled into sperm ropes or spermatophores. The female portion of the duct is more complex. Soon after quitting the uterus it is joined by a long duct leading from a glandular sac, the spermatheca (*R.f*). In this duct and sac the spermatophores received in copulation from another snail are lodged. In *Helix hortensis* the spermatheca is simple. In other species of Helix a second duct (as large in *Helix aspersa* as the chief one) is given off from the spermathecal duct, and in the natural state is closely adherent to the wall of the uterus. This second duct has normally no spermathecal gland at its termination, which is simple and blunt. But in rare cases in *Helix aspersa* a second spermatheca is found at the end of this second duct. Tracing the widening female duct onwards we now come to the openings of the digitate accessory glands *d*, *d*, which probably assist in the formation of the egg-capsule. Close to them is the remarkable dart-sac *ps*, a thick-walled sac, in the lumen of which a crystalline four-fluted rod or dart consisting of carbonate of lime is found. It is supposed to act in some way as a stimulant in copulation, but possibly has to do with the calcareous covering of the egg-capsule. Other Pulmonata exhibit variations of secondary importance in the details of this hermaphrodite apparatus.

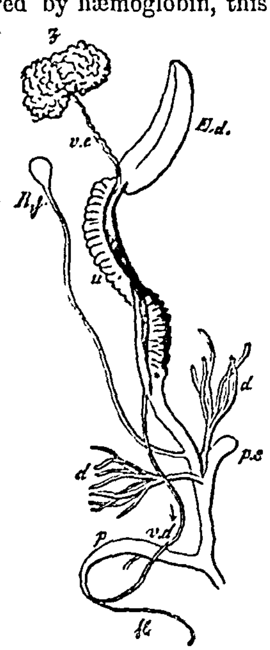

FIG. 72*.—Hermaphrodite reproductive apparatus of the Garden Snail (*Helix hortensis*). *z*, ovo-testis; *v.e*, hermaphrodite duct; *E.d.*, albuminiparous gland; *u*, uterine dilatation of the hermaphrodite duct; *d*, digitate accessory glands on the female duct; *p.s*, calciferous gland or dart-sac on the female duct; *R.f*, spermatheca or receptacle of the sperm in copulation, opening into the female duct; *v.d*, male duct (vas deferens); *p*, penis; *fl.*, flagellum.

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The shell of the Pulmonata, though always light and delicate, is in many cases a well-developed spiral "house," into which the creature can withdraw itself; and, although the foot possesses no operculum, yet in Helix the aperture of the shell is closed in the winter by a complete lid, the "hybernaculum," more or less calcareous in nature, which is secreted by the foot. In Clausilia a peculiar modification of this lid exists permanently in the adult, attached by an elastic stalk to the mouth of the shell, and known as the "clausilium." In Limnæus the permanent shell is preceded in the embryo by a well-marked shell-gland or primitive shell-sac (fig. 72***), at one time supposed to be the developing anus, but shown by Lankester to be identical with the "shell-gland" discovered by him in other Mollusca (Pisidium, Pleurobranchidium, Neritina, &c.). As in other Gastropoda Anisopleura, this shell-sac may abnormally develop a plug of chitonous matter, but normally it flattens out and disappears, whilst the cap-like rudiment of the permanent shell is shed out from the dome-like surface

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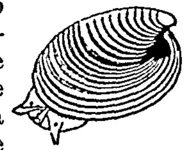

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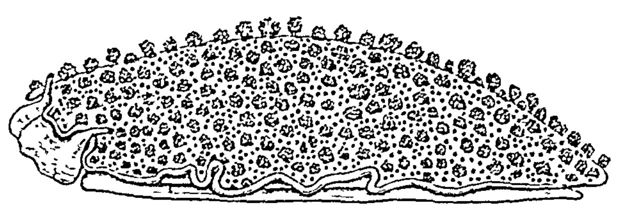

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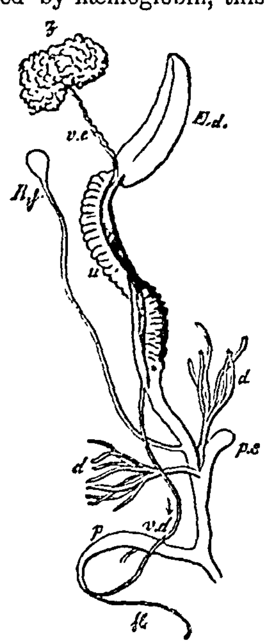

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"mesoblasts," which bud off from the invaginated arch-enteron, partly to cells derived from the ectoderm, which at a very early stage is connected by long processes with the invaginated endoderm, as shown in fig. 3, D. The external form of the embryo goes through the same changes as in other Gastropods, and is not, as was held previously to Lankester's observations, exceptional. When the middle and hinder regions of the blastopore are closing in, an equatorial ridge of ciliated cells is formed, converting the embryo into a typical "Trochosphere" (fig. 4, E, F).

The foot now protrudes below the mouth (fig. 4), and the post-oral hemisphere of the Trochosphere grows more rapidly than the anterior or velar area. The young foot shows a bilobed form (fig. 4, D, *f*). Within the velar area the eyes and the cephalic tentacles commence to rise up (fig. 4, D, *t*), and on the surface of the post-oral region is formed a cap-like shell and an encircling ridge, which gradually increases in prominence and becomes the freely depending mantle-skirt. The outline of the velar area becomes strongly emarginated and can be traced through the more mature embryos to the cephalic lobes or labial processes of the adult Limnæus (fig. 70).

This permanence of the distinction of the part known as the velar area through embryonic life to the adult state is exceptional among Mollusca, and is therefore a point of especial interest in Limnæus. None of the figures of adult Limnæus in recent works on Zoology show properly the form of the head and these velar lobes, and accordingly the figures here given have been specially sketched for the present article. The increase of the visceral dome, its spiral twisting, and the gradual closure of the space overhung by the mantle-skirt so as to convert it into a lung-sac with a small contractile aperture, belong to stages in the development later than any represented in our figures.

We may now revert briefly to the internal organization at a period when the Trochosphere is beginning to show a prominent foot growing out from the area where the mid-region of the elongated blastopore was situated, and having therefore at one end of it the mouth and at the other the anus. Fig. 72*** represents such an embryo under slight compression as seen by transmitted light. The ciliated band of the left side of the velar area is indicated by a line extending from *v* to *v*; the foot *f* is seen between the pharynx *ph* and the pedicle of invagination *pi*. The mass of the arch-enteron or invaginated endodermal sac has taken on a bilobed form (compare Pisidium, fig. 151), and its cells are swollen (*gs* and *tge*). This bilobed sac becomes entirely the liver in the adult; the intestine and stomach are formed from the pedicle of invagination, whilst the pharynx, œsophagus, and crop form from the stomodæal invagination *ph*. To the right (in the figure) of the rectal peduncle is seen the deeply invaginated shell-gland *ss*, with a secretion *sh* protruding from it. The shell-gland is destined in Limnæus to become very rapidly stretched out, and to disappear. Farther up, within the velar area, the rudiments of the cerebral nerve-ganglion *ng* are seen separating from the ectoderm. A remarkable cord of cells having a position just below the integument occurs on each side of the head. In the figure the cord of the left side is seen, marked *re*. This paired organ consists of a string of cells which are perforated by a duct. The opening of the duct at either end is not known. Such cannulated cells are characteristic of the nephridia of many worms, and it is held that the organs thus formed in the embryo Limnæus are embryonic nephridia. The most important fact about them is that they disappear, and are in no way connected with the typical nephridium of the adult. In reference to their first observer they are conveniently called "Stiebel's canals." Other Pulmonata possess, when embryos, Stiebel's canals in a more fully-developed state, for instance the common slug Limax (fig. 72**, *pk*). Here too they disappear during embryonic life. Further knowledge concerning them is greatly needed. It is not clear whether there is anything equivalent to them in the embryos of marine Gastropoda or other Mollusca, the ectodermal cells called "embryonic renal organs" in some Gastropod embryos having only a remote resemblance to them. The three pairs of transient embryonic nephridia of the medicinal leech, the ciliated cephalic pits of Nemertines, and the anterior nephridia of Gephyræans, all suggest themselves for comparison with these enigmatical canals.

Marine Pulmonata.—Whilst the Pulmonata are essentially a terrestrial and fresh-water group, there is one genus of slug-like Pulmonates which frequent the sea-coast (Peronia, fig. 72), whilst their immediate congeners (Onchidium) are found in marshes of brackish water. Semper (33) has shown that these slugs have, in addition to the usual pair of cephalic eyes, a number of eyes developed upon the dorsal integument. These dorsal eyes are very perfect in elaboration, possessing lens, retinal nerve-end cells, retinal pigment, and optic nerve. Curiously enough, however, they differ from the cephalic Molluscan eye (for an account of which see fig. 118) in the fact that, as in the vertebrate eye, the filaments of the optic nerve penetrate the retina, and are connected with the surfaces of the nerve-end cells nearer the lens instead of with the opposite end. The significance of this arrangement is not known, but it is important to note, as shown by Hensen, Hickson, and others, that in the bivalves Pecten and Spondylus, which also have eyes upon the mantle quite distinct from typical cephalic eyes, there is the same relationship as in Onchidiadæ of the optic nerve to the retinal cells (fig. 145). In both Onchidiadæ and Pecten the pallial eyes have probably been developed by the modification of tentacles, such as coexist in an unmodified form with the eyes. The Onchidiadæ are, according to Semper, pursued as food by the leaping fish Periophthalmus, and the dorsal eyes are of especial value to them in aiding them to escape from this enemy.

Class II.—SCAPHOPODA.

Characters.—Mollusca Glossophora with the FOOT adapted to a BURROWING life in sand (figs. 73, 74, *f*). The body,

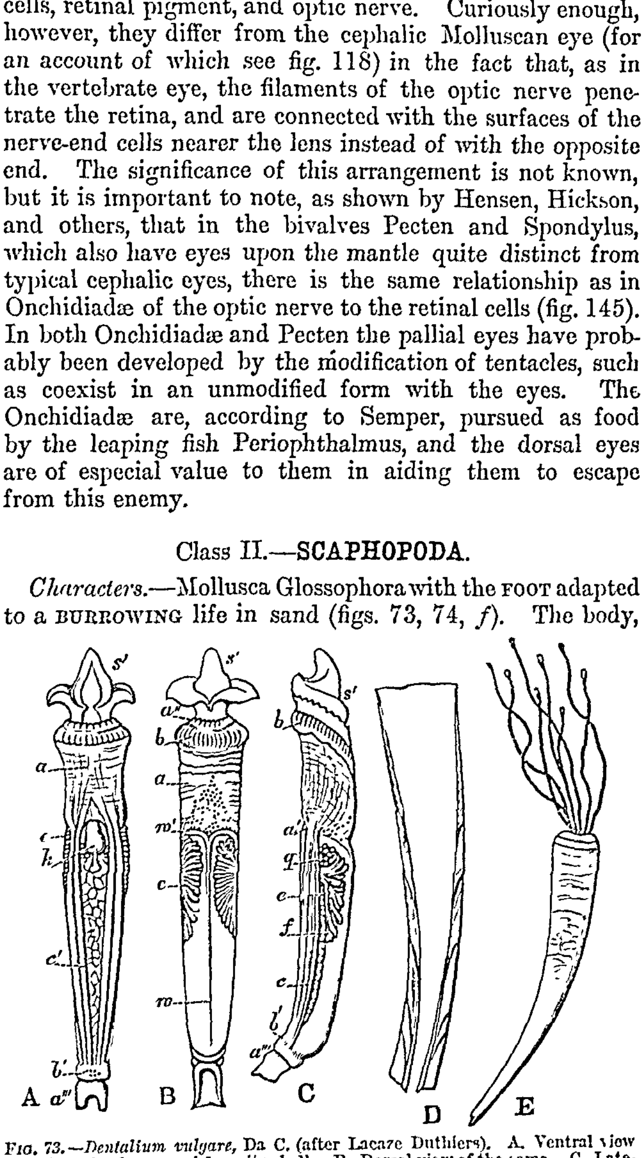

FIG. 73.—*Dentalium vulgare*, Da C. (after Lacaze Duthiers). A. Ventral view of the animal removed from its shell. B. Dorsal view of the same. C. Lateral view of the same. D. The shell in section. E. Surface view of the shell with gill-tentacles exserted as in life. *a*, mantle; *a'*, longitudinal muscle; *a''*, fringe surrounding the anterior opening of the mantle-chamber; *a'''*, the posterior appendix of the mantle; *b*, anterior circular muscle of the mantle; *b'*, posterior do.; *c*, *c'*, longitudinal muscle of mantle; *e*, liver; *f*, gonad; *k*, buccal mass (showing through the mantle); *q*, left nephridium; *s'*, club-shaped extremity of the foot; *w*, *w'*, longitudinal blood-sinus of the mantle.

and to a much greater extent the mantle-skirt and the foot, are elongated along the primitive antero-posterior (oro-anal)

"mesoblasts," which bud off from the invaginated arch-enteron, partly to cells derived from the ectoderm, which at a very early stage is connected by long processes with the invaginated endoderm, as shown in fig. 3, D. The external form of the embryo goes through the same changes as in other Gastropods, and is not, as was held previously to Lankester's observations, exceptional. When the middle and hinder regions of the blastopore are closing in, an equatorial ridge of ciliated cells is formed, converting the embryo into a typical "Trochosphere" (fig. 4, E, F).

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This permanence of the distinction of the part known as the velar area through embryonic life to the adult state is exceptional among Mollusca, and is therefore a point of especial interest in Limnæus. None of the figures of adult Limnæus in recent works on Zoology show properly the form of the head and these velar lobes, and accordingly the figures here given have been specially sketched for the present article. The increase of the visceral dome, its spiral twisting, and the gradual closure of the space overhung by the mantle-skirt so as to convert it into a lung-sac with a small contractile aperture, belong to stages in the development later than any represented in our figures.

We may now revert briefly to the internal organization at a period when the Trochosphere is beginning to show a prominent foot growing out from the area where the mid-region of the elongated blastopore was situated, and having therefore at one end of it the mouth and at the other the anus. Fig. 72*** represents such an embryo under slight compression as seen by transmitted light. The ciliated band of the left side of the velar area is indicated by a line extending from *v* to *v*; the foot *f* is seen between the pharynx *ph* and the pedicle of invagination *pi*. The mass of the arch-enteron or invaginated endodermal sac has taken on a bilobed form (compare Pisidium, fig. 151), and its cells are swollen (*gs* and *tge*). This bilobed sac becomes *entirely* the liver in the adult; the intestine and stomach are formed from the pedicle of invagination, whilst the pharynx, œsophagus, and crop form from the stomodæal invagination *ph*. To the right (in the figure) of the rectal peduncle is seen the deeply invaginated shell-gland *ss*, with a secretion *sh* protruding from it. The shell-gland is destined in Limnæus to become very rapidly stretched out, and to disappear. Farther up, within the velar area, the rudiments of the cerebral nerve-ganglion *ng* are seen separating from the ectoderm. A remarkable cord of cells having a position just below the integument occurs on each side of the head. In the figure the cord of the left side is seen, marked *re*. This paired organ consists of a string of cells which are perforated by a duct. The opening of the duct at either end is not known. Such cannulated cells are characteristic of the nephridia of many worms, and it is held that the organs thus formed in the embryo Limnæus are embryonic nephridia. The most important fact about them is that they disappear, and are in no way connected with the typical nephridium of the adult. In reference to their first observer they are conveniently called "Stiebel's canals." Other Pulmonata possess, when embryos, Stiebel's canals in a more fully-developed state, for instance the common slug Limax (fig. 72**, *pk*). Here too they disappear during embryonic life. Further knowledge concerning them is greatly needed. It is not clear whether there is anything equivalent to them in the embryos of marine Gastropoda or other Mollusca, the ectodermal cells called "embryonic renal organs" in some Gastropod embryos having only a remote resemblance to them. The three pairs of transient embryonic nephridia of the medicinal leech, the ciliated cephalic pits of Nemertines, and the anterior nephridia of Gephyræans, all suggest themselves for comparison with these enigmatical canals.

Marine Pulmonata.—Whilst the Pulmonata are essentially a terrestrial and fresh-water group, there is one genus of slug-like Pulmonates which frequent the sea-coast (Peronia, fig. 72), whilst their immediate congeners (Onchidium) are found in marshes of brackish water. Semper (33) has shown that these slugs have, in addition to the usual pair of cephalic eyes, a number of eyes developed upon the dorsal integument. These dorsal eyes are very perfect in elaboration, possessing lens, retinal nerve-end cells, retinal pigment, and optic nerve. Curiously enough, however, they differ from the cephalic Molluscan eye (for an account of which see fig. 118) in the fact that, as in the vertebrate eye, the filaments of the optic nerve penetrate the retina, and are connected with the surfaces of the nerve-end cells nearer the lens instead of with the opposite end. The significance of this arrangement is not known, but it is important to note, as shown by Hensen, Hickson, and others, that in the bivalves Pecten and Spondylus, which also have eyes upon the mantle quite distinct from typical cephalic eyes, there is the same relationship as in Onchidiadæ of the optic nerve to the retinal cells (fig. 145). In both Onchidiadæ and Pecten the pallial eyes have probably been developed by the modification of tentacles, such as coexist in an unmodified form with the eyes. The Onchidiadæ are, according to Semper, pursued as food by the leaping fish Periophthalmus, and the dorsal eyes are of especial value to them in aiding them to escape from this enemy.

Class II.—SCAPHOPODA.

Characters.—Mollusca Glossophora with the FOOT adapted to a BURROWING life in sand (figs. 73, 74, *f*). The body,

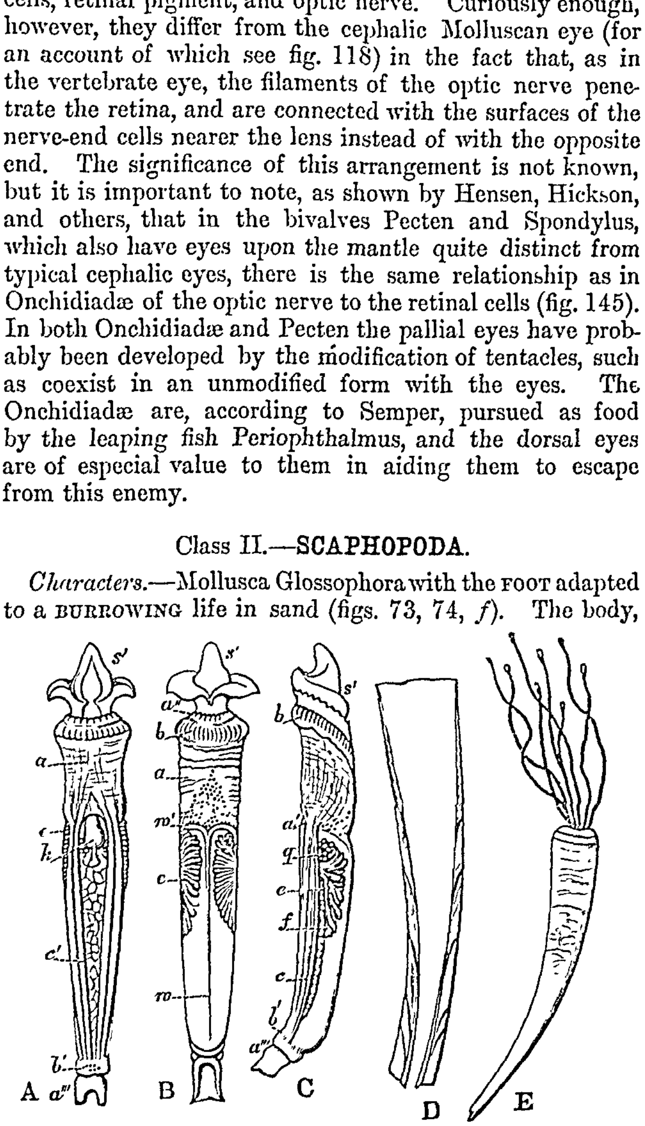

FIG. 73.—*Dentalium vulgare*, Da C. (after Lacaze Duthiers). A. Ventral view of the animal removed from its shell. B. Dorsal view of the same. C. Lateral view of the same. D. The shell in section. E. Surface view of the shell with gill-tentacles exserted as in life. *a*, mantle; *a'*, longitudinal muscle; *a''*, fringe surrounding the anterior opening of the mantle-chamber; *a'''*, the posterior appendix of the mantle; *b*, anterior circular muscle of the mantle; *b'*, posterior do.; *c*, *c'*, longitudinal muscle of mantle; *e*, liver; *f*, gonad; *k*, buccal mass (showing through the mantle); *q*, left nephridium; *s'*, club-shaped extremity of the foot; *w*, *w'*, longitudinal blood-sinus of the mantle.

and to a much greater extent the mantle-skirt and the foot, are elongated along the primitive antero-posterior (oro-anal)

like processes, either very short and conical (Clio, Eurybia), or lengthy (Pneumodermon, Octopus); these may be beset with suckers or hooks, or both. The mid-foot (fig. 75, *mf*) is expanded into a pair of muscular lobes right and left, which either are used for striking the water like the wings of a butterfly (Pteropoda), or are bent round towards one another so that their free margins meet and constitute a short tube,—the siphon or funnel (Siphonopoda). The hind foot is either very small or absent.

A distinctive feature of the Cephalopoda is the ABSENCE of anything like the TORSION of the visceral mass seen in the Anisopleurous Gastropoda, although as an exception this torsion occurs in one family (the Limacinidæ).

The ANUS, although it may be a little displaced from the median line, is (except in Limacinidæ) approximately median and posterior. The MANTLE-SKIRT may be aborted (Gymnosomatous Pteropoda); when present it is deeply produced posteriorly, forming a large sub-pallial chamber around the anus. As in our schematic Mollusc, by the side of the anus are placed the single or paired apertures of the NEPHRIDIA, the GENITAL APERTURES (paired only in Nautilus, in female Octopoda, female Ommastrephes, and male Eledone), and the paired CTENIDIA (absent in all Pteropoda). The VISCERAL HUMP or dome is elevated, and may be very much elongated (see fig. 75, (4), (5), (6)) in a direction almost at right angles to the primary horizontal axis (A, P in fig. 75) of the foot.

A SHELL is frequently, but not invariably, secreted on the visceral hump and mantle-skirt of Cephalopoda; but there are both Pteropoda and Siphonopoda devoid of any shell. The shell is usually light in substance or lightened by air-chambers in correlation with the free-swimming habits of the Cephalopoda. It may be external, when it is box-like or boat-like, or internal, when it is plate-like. Very numerous minute pigmented sacs capable of expansion and contraction, and known as CHROMATOPHORES, are usually present in the integument in both branches of the class. The GONADS of both sexes are developed in one individual in some Cephalopoda (Pteropoda), in others the sexes are separate.

SENSE-ORGANS, especially the cephalic eyes and the otocysts, are very highly developed in the higher Cephalopoda. The osphradia have the typical form and position in the lower forms, but appear to be more or less completely replaced by other olfactory organs in the higher. The normal NERVE-GANGLIA are present, but the connectives are shortened, and the ganglia concentrated and fused in the cephalic region. Large special ganglia (optic, stellate, and supra-buccal) are developed in the higher forms (Siphonopoda).

The Cephalopoda exhibit a greater range from low to high organization than any other Molluscan class, and hence they are difficult to characterize in regard to several groups of organs; but they are definitely held together by the existence in all of the encroachment of the fore-foot so as

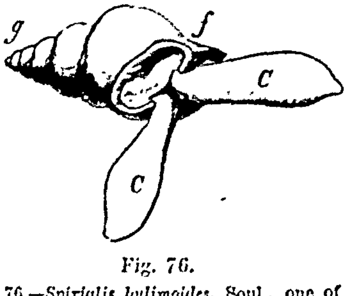

Fig. 76.

Fig. 77.

FIG. 76.—*Spirialis bulimoides*, Soul., one of the Limacinidæ enlarged (from Owen). *C C*, pteropodial lobes of the mid-foot; *f*, operculum carried on the hind-foot; *g*, spiral shell.
FIG. 77.—Operculum of Spirialis enlarged.

to surround the head, and by the functionally important BILOBATION OF THE MID-FOOT.

Two very distinct branches of the Cephalopoda are to be recognized: the one, the Pteropoda, more archaic in the condition of its bilobed mid-foot, including a number of minute, and in all probability degenerate, oceanic forms of simplified and obscure organization; the other, the Siphonopoda, containing the Pearly Nautilus and the Cuttles, which have for ages (as their fossil remains show) dominated among the inhabitants of the sea, being more highly gifted in special sense, more varied in movement, more powerful in proportion to size, and more heavily equipped with destructive weapons of offence than any other marine organisms.

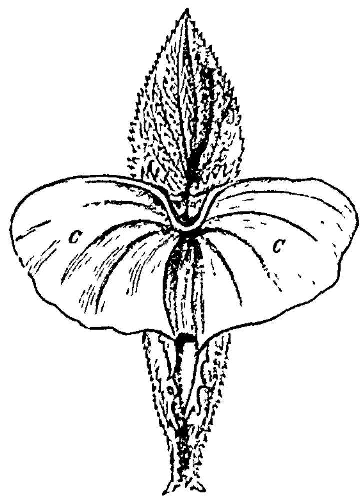

FIG. 77a.—*Cymbulia Peronii*, Cuvier (from Owen). *C, C*, the expanded pteropodial lobes or wing-like fins of the mid-foot.

Branch *a*.—*PTEROPODA*.

Characters.—Cephalopoda in which the mid-region of the foot is (as compared with the Siphonopoda) in its more primitive condition, being relatively largely developed and drawn out into a pair of wing-like muscular lobes (identical with the two halves of the siphon of the Siphonopoda) which are used as paddles (see figs. 76-86). The hind-region of the foot is often aborted, but may carry an operculum (figs. 76, 77). The fore-region of the foot (that embracing the head) is also often rudimentary, but may be drawn out into one or more pairs of tentacles, simulating cephalic tentacles, and provided with suckers (figs. 84, 85).

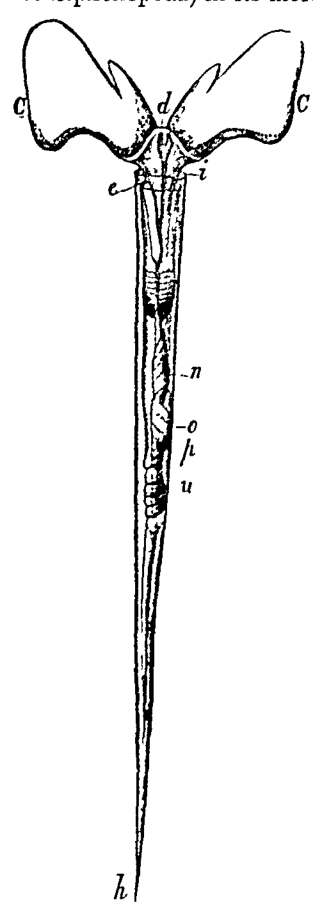

FIG. 78.—*Styliola acicula*, Rang. sp. enlarged (from Owen). *C, C*, the wing-like lobes of the mid-foot; *d*, median fold of same; *e*, copulatory organ; *h*, pointed extremity of the shell; *i*, anterior margin of the shell; *n*, stomach *o*, liver; *u*, hermaphrodite gonad.

Though the visceral hump is not twisted except in the Limacinidæ (fig. 76), there is a very general tendency to one-sided development of the viscera, and of their external apertures (as contrasted with Siphonopoda). *The ctenidia* are aborted, with the possible exception of the processes (fig. 85, *c*) at the end of the body of Pneumodermon. The vascular system resembles that of the Gastropoda. The nephridium is a single tubular body corresponding to the right nephridium of the typical pair of the archi-Mollusc. The anal aperture is usually placed a little to the left of the median line, more rarely to the right. In the Limacinidæ it has an exceptional position, owing to the torsion of the visceral mass, as in Anisopleurous Gastropoda.

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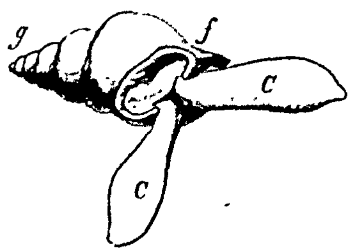

Fig. 76.

Fig. 77.

FIG. 76.—*Spirialis bulimoides*, Soul., one of the Limacinidæ enlarged (from Owen). *C C*, pteropodial lobes of the mid-foot; *f*, operculum carried on the hind-foot; *g*, spiral shell.
FIG. 77.—Operculum of Spirialis enlarged.

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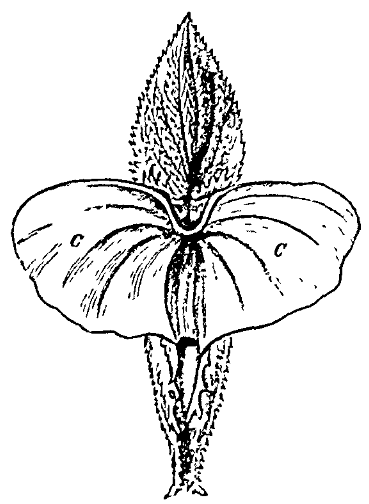

FIG. 77*a*.—*Cymbulia Peronii*, Cuvier (from Owen). *C, C*, the expanded pteropodial lobes or wing-like fins of the mid-foot.

Branch *a*.—*PTEROPODA*.

Characters.—Cephalopoda in which the mid-region of the foot is (as compared with the Siphonopoda) in its more primitive condition, being relatively largely developed and drawn out into a pair of wing-like muscular lobes (identical with the two halves of the siphon of the Siphonopoda) which are used as paddles (see figs. 76-86). The hind-region of the foot is often aborted, but may carry an operculum (figs. 76, 77). The fore-region of the foot (that embracing the head) is also often rudimentary, but may be drawn out into one or more pairs of tentacles, simulating cephalic tentacles, and provided with suckers (figs. 84, 85).

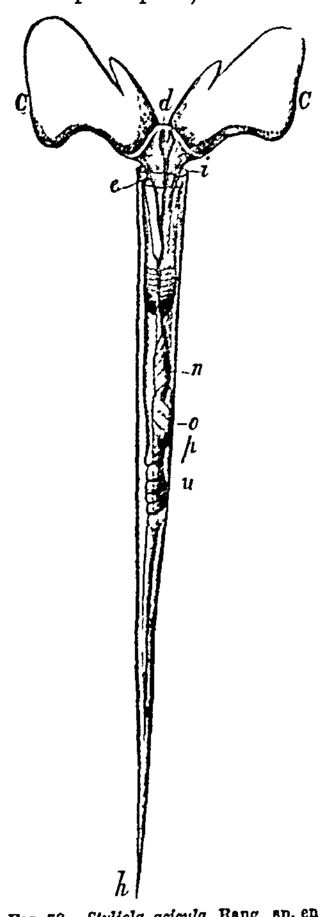

FIG. 78.—*Styliola acicula*, Rang. sp. enlarged (from Owen). *C, C*, the wing-like lobes of the mid-foot; *d*, median fold of same; *e*, copulatory organ; *h*, pointed extremity of the shell; *i*, anterior margin of the shell; *n*, stomach *o*, liver; *u*, hermaphrodite gonad.

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The fore-part of the foot which surrounds the mouth, as in all Cephalopoda, is drawn out into four or five pairs of lobes, sometimes short, but usually elongated and even filiform. These lobes either carry peculiar sheathed tentacles (*Nautilus*), or, on the other hand, acetabuliform suckers, which may be associated with claw-like hooks (Dibranchiata). The hind-foot is probably represented by the valve which depends from the inner wall of the siphon in many cases.

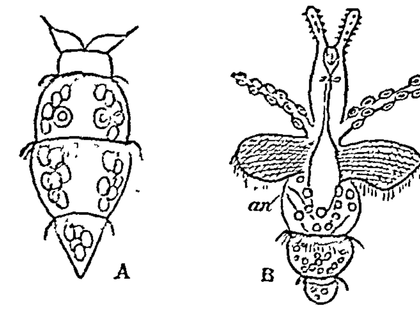

Fig. 84.

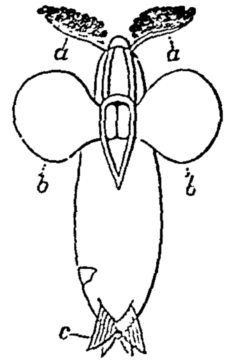

Fig. 85.

Fig. 84.—Larvæ of Pneumodermon (from Balfour, after Gegenbaur). The præ-oral ciliated band of the trochosphere stage (velum) has atrophied. In A three post-oral circlets of cilia are present. The otocysts are seen, and the rudiments of a pair of processes growing from the head. In B the foremost ciliated ring has disappeared; the cephalic region is greatly developed, and, as compared with the adult (fig. 85), is large and free; the pair of hook-bearing processes on each side of the mouth are retractile, probably part of the fore-foot. At the base of the cephalic snout are seen the pair of arm-like processes (fore-foot) provided with suckers, and behind these the broad pteropodial lobes or wing-like fins of the mid-foot.

Fig. 85.—*Pneumodermon violaceum*, d'Orb.; magnified five diameters. *a*, the sucker-bearing arms; *b*, the fins of the mid-foot (in the middle line, between these, is seen the sucker-like median portion of the foot, by means of which the animal can crawl as a Gastropod); *c*, the four branchial processes. (After Keferstein.)

A shell (figs. 89, 100) is very generally present, affording protection to the visceral mass and attachment for muscles. It may be external or enclosed in dorsal upgrowing folds of the mantle, which (except in Spirula) close up at an early period of development, so as to form a shut sac in which the shell is secreted. The ctenidia are well developed as paired gill-plumes, serving as the efficient branchial organs (figs. 101, 103, and fig. 2, B).

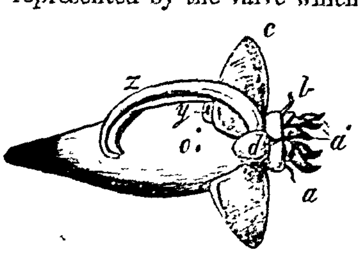

Fig. 86.—*Clione borealis*, L.; magnified two diameters,—postero-ventral aspect. *a*, the cephalic region carrying *a′*—three pairs of cephalic cones provided each with very numerous minute sucker-like processes, and surrounded by a hood-like upgrowth,—and *b*, the more elongated tentacles (the retractile eye-tentacles are not seen, being placed dorsally); *c*, the pteropodial fins; *d*, the median portion of the foot; *o*, the anus; *y*, the vagina; *z*, the penis. (From Owen, after Eschricht.)

The vascular system is very highly developed; the heart consists of a pair of auricles and a ventricle (figs. 104, 105). Branchial hearts are formed on the advehent vessels of the branchiæ. It is not known to what extent the minute subdivision of the arteries extends, or whether there is a true capillary system.

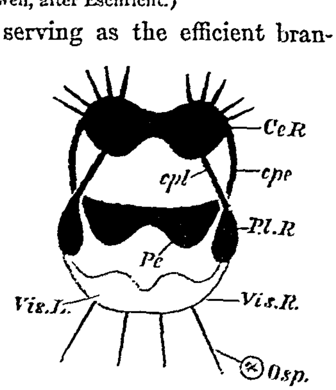

Fig. 87.—Enlarged diagram of the nerve-centres of Pneumodermon (from Spengel, after Souleyet). *CeR*, right cerebral ganglion; *Pl.R*, right pleural ganglion; *Pe*, right pedal ganglion; *Vis.R.*, right visceral ganglion; *Vis.L.*, left visceral ganglion; *cpe*, right cerebro-pedal connective; *cpl*, right cerebro-pleural connective; *Osp.*, osphradium connected by a nerve with the right visceral ganglion.

The pericardium is extended so as to form a very large sac passing among the viscera dorsal wards and sometimes containing the ovary or testis—the viscero-pericardial sac—which opens to the exterior either directly or through the nephridia. It has no connexion with the vascular system. The nephridia are always paired sacs, the walls of which invest the branchial advehent vessels (figs. 104, 108). They open each by a pore into the viscero-pericardial sac except in Nautilus. The anal aperture is median and raised on a papilla. Jaws (fig. 88, *e*) and a lingual ribbon (fig. 107) are well developed. The jaws have the form of a pair of powerful beaks, either horny or calcified (Nautilus), and are capable of inflicting severe wounds.

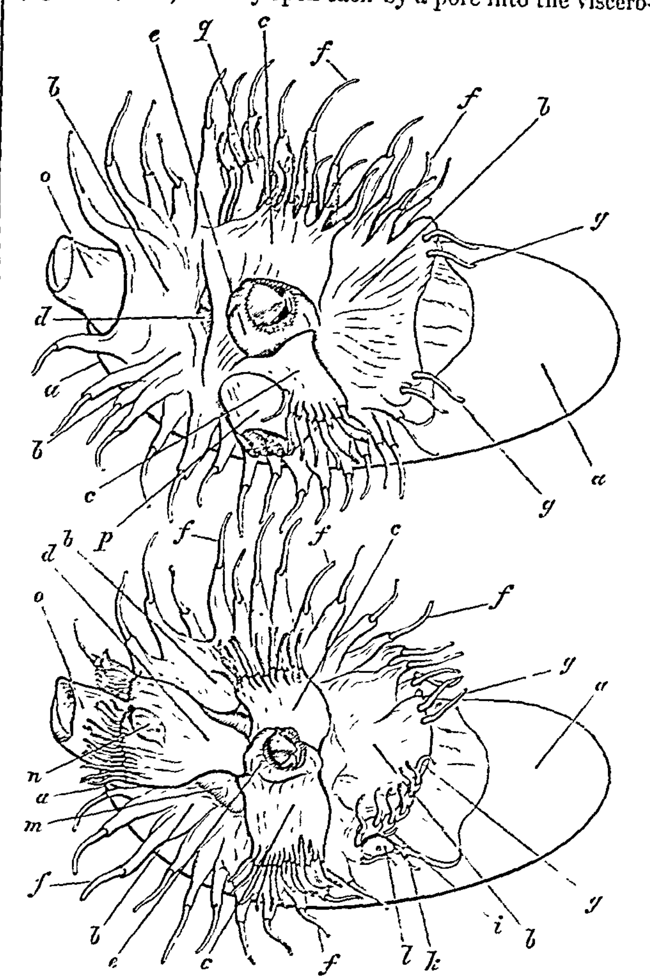

Fig. 88.—Male (upper) and female (lower) specimens of *Nautilus pompilius* as seen in the expanded condition, the observer looking down on to the buccal cone *e*; one-third the natural size linear. The drawings have been made from actual specimens by A. G. Bourne, B.Sc., and serve to show the natural disposition of the tentaculiferous lobes and tentacles of the circum-oral portion of the foot in the living state, as well as the great differences between the two sexes. *a*, the shell; *b*, the *outer* ring-like expansion (annular lobe) of the circum-oral muscular mass of the fore-foot, carrying nineteen tentacles on each side—posteriorly this is enlarged to form the "hood" (marked *v* in fig. 89 and *m*. in figs. 90 and 91), giving off the pair of tentacles marked *g* in the present figure; *c*, the right and left inner lobes of the fore-foot, each carrying twelve tentacles in the female, in the male subdivided into *p*, the "spadix" or hectocotylus on the left side, and *q*, the "anti-spadix," a group of four tentacles on the right side,—it is thus seen that the subdivided right and left inner lobes of the male correspond to the undivided right and left inner lobes of the female; *d*, the inner inferior lobe of the fore-foot, a bilateral structure in the female carrying two groups, each of fourteen tentacles, separated from one another by a lamellated organ *n*, supposed to be olfactory in function—in the male the inner inferior lobe of the fore-foot is very much reduced, and has the form of a paired group of lamellæ (*d* in the upper figure); *e*, the buccal cone, rising from the centre of the three inner lobes, and fringing the protruded calcareous beaks or jaws with a series of minute papillæ; *f*, the tentacles of the outer circum-oral lobe or annular lobe of the fore-foot projecting from their sheaths; *g*, the two most posterior tentacles of this series belonging to that part of the annular lobe which forms the hood (*m*. in figs. 90 and 91); *i*, superior ophthalmic tentacle; *k*, inferior ophthalmic tentacle; *l*, eye; *m*, paired laminated organ on each side of the base of the inner inferior lobe (*d*) of the female, probably olfactory in function; *n*, olfactory lamellæ upon the inner inferior lobe (in the female); *o*, the siphon (mid-foot); *p*, the spadix (in the male), the hectocotylized portion of the left inner lobe of the fore-foot representing four modified tentacles, eight being left unmodified; *q*, the anti-spadix (in the male), being four of the twelve tentacles of the right inner lobe of the fore-foot isolated from the remaining eight, and representing on the right side the differentiated spadix of the left side. The four tentacles of the anti-spadix are set, three on one base and one on a separate base.

There are thus in the female, where they are most numerous, ninety-four tentacles, thirty-eight on the outer annular lobe, four ophthalmic (a pair to each eye), twelve on each of the right and left inner lobes, and twenty-eight on the inner inferior lobe.

The fore-part of the foot which surrounds the mouth, as in all Cephalopoda, is drawn out into four or five pairs of lobes, sometimes short, but usually elongated and even fili-

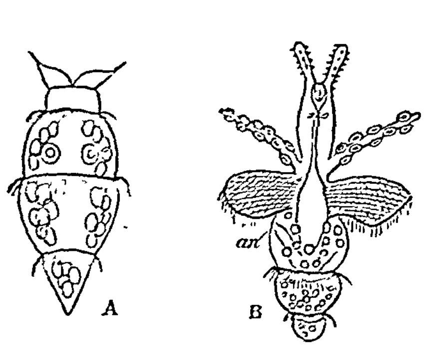

Fig. 84.

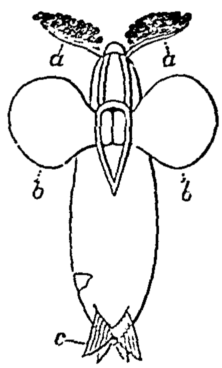

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FIG. 84.—*Larvæ of Pneumodermon* (from Balfour, after Gegenbaur). The pre-oral ciliated band of the trochosphere stage (velum) has atrophied. In A three post-oral circlets of cilia are present. The otocysts are seen, and the rudiments of a pair of processes growing from the head. In B the foremost ciliated ring has disappeared; the cephalic region is greatly developed, and, as compared with the adult (fig. 85), is large and free; the pair of hook-bearing processes on each side of the mouth are retractile, probably part of the fore-foot. At the base of the cephalic snout are seen the pair of arm-like processes (fore-foot) provided with suckers, and behind these the broad pteropodial lobes or wing-like fins of the mid-foot.

FIG. 85.—*Pneumodermon violaceum*, d'Orb.; magnified five diameters. *a*, the sucker-bearing arms; *b*, the fins of the mid-foot (in the middle line, between these, is seen the sucker-like median portion of the foot, by means of which the animal can crawl as a Gastropod); *c*, the four branchial processes. (After Keferstein.)

form. These lobes either carry peculiar sheathed tentacles (Nautilus), *or, on the other hand, acetabuliform suckers*, which may be associated with claw-like hooks (Dibranchiata). The hind-foot is probably represented by the valve which depends from the inner wall of the siphon in many cases.

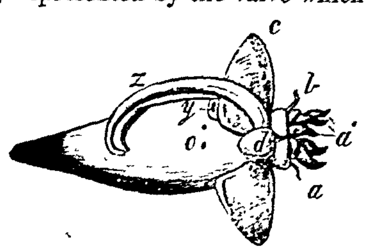

FIG. 86.—*Clione borealis*, L.; magnified two diameters,—postero-ventral aspect. *a*, the cephalic region carrying *a'*—three pairs of cephalic cones provided each with very numerous minute sucker-like processes, and surrounded by a hood-like upgrowth,—and *b*, the more elongated tentacles (the retractile eye-tentacles are not seen, being placed dorsally); *c*, the pteropodial fins; *d*, the median portion of the foot; *o*, the anus; *y*, the vagina; *z*, the penis. (From Owen, after Eschricht.)

A shell (figs. 89, 100) is very generally present, affording protection to the visceral mass and attachment for muscles. It may be external or enclosed in dorsal upgrowing folds of the mantle, which (except in Spirula) close up at an early period of development, so as to form a shut sac in which the shell is secreted. The ctenidia are well developed as paired gill-plumes, serving as the efficient branchial organs (figs. 101, 103, and fig. 2, B).

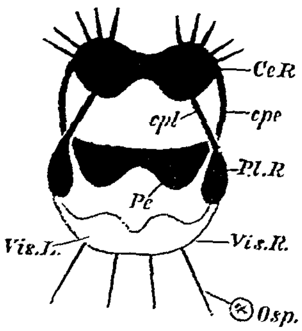

FIG. 87.—Enlarged diagram of the nerve-centres of Pneumodermon (from Spengel, after Souleyet). *CeR*, right cerebral ganglion; *Pl.R*, right pleural ganglion; *Pe*, right pedal ganglion; *Vis.R.*, right visceral ganglion; *Vis.L.*, left visceral ganglion; *cpe*, right cerebro-pedal connective; *cpl*, right cerebro-pleural connective; *Osp.*, osphradium connected by a nerve with the right visceral ganglion.

The vascular system is very highly developed; the heart consists of a pair of auricles and a ventricle (figs. 104, 105). Branchial hearts are formed on the advehent vessels of the branchiæ. It is not known to what extent the minute subdivision of the arteries extends, or whether there is a true capillary system.

The pericardium is extended so as to form a very large sac passing among the viscera dorsal wards and sometimes containing the ovary or testis—the viscero-pericardial sac—which opens to the exterior either directly or through the nephridia. It has no connexion with the vascular system. The nephridia are always paired sacs, the walls of which invest the branchial advehent vessels (figs. 104, 108). They open each by a pore into the viscero-

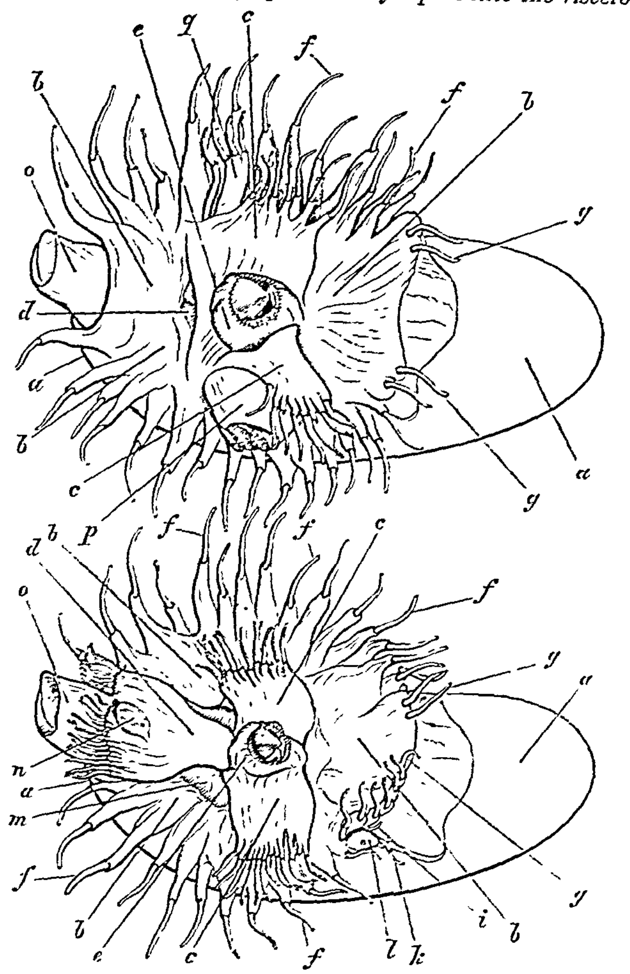

FIG. 88.—Male (upper) and female (lower) specimens of *Nautilus pompilius* as seen in the expanded condition, the observer looking down on to the buccal cone *e*; one-third the natural size linear. The drawings have been made from actual specimens by A. G. Bourne, B.Sc., and serve to show the natural disposition of the tentaculiferous lobes and tentacles of the circum-oral portion of the foot in the living state, as well as the great differences between the two sexes. *a*, the shell; *b*, the *outer* ring-like expansion (annular lobe) of the circum-oral muscular mass of the fore-foot, carrying nineteen tentacles on each side—posteriorly this is enlarged to form the "hood" (marked *v* in fig. 89 and *m.* in figs. 90 and 91), giving off the pair of tentacles marked *g* in the present figure; *c*, the right and left inner lobes of the fore-foot, each carrying twelve tentacles in the female, in the male subdivided into *p*, the "spadix" or hectocotylus on the left side, and *q*, the "anti-spadix," a group of four tentacles on the right side,—it is thus seen that the subdivided right and left inner lobes of the male correspond to the undivided right and left inner lobes of the female; *d*, the inner inferior lobe of the fore-foot, a bilateral structure in the female carrying two groups, each of fourteen tentacles, separated from one another by a lamellated organ *n*, supposed to be olfactory in function—in the male the inner inferior lobe of the fore-foot is very much reduced, and has the form of a paired group of lamellæ (*d* in the upper figure); *e*, the buccal cone, rising from the centre of the three inner lobes, and fringing the protruded calcareous beaks or jaws with a series of minute papillæ; *f*, the tentacles of the outer circum-oral lobe or annular lobe of the fore-foot projecting from their sheaths; *g*, the two most posterior tentacles of this series belonging to that part of the annular lobe which forms the hood (*m.* in figs. 90 and 91); *i*, superior ophthalmic tentacle; *k*, inferior ophthalmic tentacle; *l*, eye; *m*, paired laminated organ on each side of the base of the inner inferior lobe (*d*) of the female, probably olfactory in function; *n*, olfactory lamellæ upon the inner inferior lobe (in the female); *o*, the siphon (mid-foot); *p*, the spadix (in the male), the hectocotylized portion of the left inner lobe of the fore-foot representing four modified tentacles, eight being left unmodified; *q*, the anti-spadix (in the male), being four of the twelve tentacles of the right inner lobe of the fore-foot isolated from the remaining eight, and representing on the right side the differentiated spadix of the left side. The four tentacles of the anti-spadix are set, three on one base and one on a separate base.

There are thus in the female, where they are most numerous, ninety-four tentacles, thirty-eight on the outer annular lobe, four ophthalmic (a pair to each eye), twelve on each of the right and left inner lobes, and twenty-eight on the inner inferior lobe.

pericardial sac except in Nautilus. The anal aperture is median and raised on a papilla. Jaws (fig. 88, *e*) and a lingual ribbon (fig. 107) are well developed. The jaws have the form of a pair of powerful beaks, either horny or calcified (Nautilus), and are capable of inflicting severe wounds.

Family 1.—*Nautilidæ.*
Genera: [*Orthoceras*], Breyn.; [*Cyrtoceras*], Goldfuss; [*Gomphoceras*], Münster; [*Phragmoceras*], Brod.; [*Gyroceras*], Meyer; [*Ascoceras*], Barrande; [*Oncoceras*], Hall; [*Lituites*], Breyn.; [*Trochoceras*], Barrande; *Nautilus*, L. (figs. 88, 89, 90, &c.); [*Clymenia*], Münst.; [*Nothoceras*], Barrande.
Family 2.—*Ammonitidæ.*
Genera: [*Bactrites*], Sanderg.; [*Goniatites*], de Haan; [*Rhabdoceras*], Hauer; [*Clydonites*], Hauer; [*Cochloceras*], Hauer; [*Baculina*], d'Orb.; [*Ceratites*], de Haan; [*Baculites*], Lam.; [*Toxoceras*], d'Orb.; [*Crioceras*], Leveillé; [*Ptychoceras*], d'Orb.; [*Hamites*], Parkinson; [*Ancyloceras*], d'Orb.; [*Scaphites*], Parkinson; [*Ammonites*], Breyn.; [*Turrilites*], Lam.; [*Helioceras*], d'Orb.; [*Heteroceras*], d'Orb.
N.B.—The names in brackets are those of extinct genera.

Order 2.—**Dibranchiata** (=Holosiphona, Acetabulifera).

Characters.—Siphonopodous Cephalopods in which the inflected lateral margins of the mid-foot are fused so as to form a complete tubular siphon (fig. 96, *i*). The circumoral lobes of the fore-foot carry suckers disposed upon them in rows (as in the Pteropod Pneumodermon), *not* tentacles (see figs. 92, 95, 96). There is a single pair of typical ctenidia (fig. 103) acting as gills (hence Dibranchiata), and

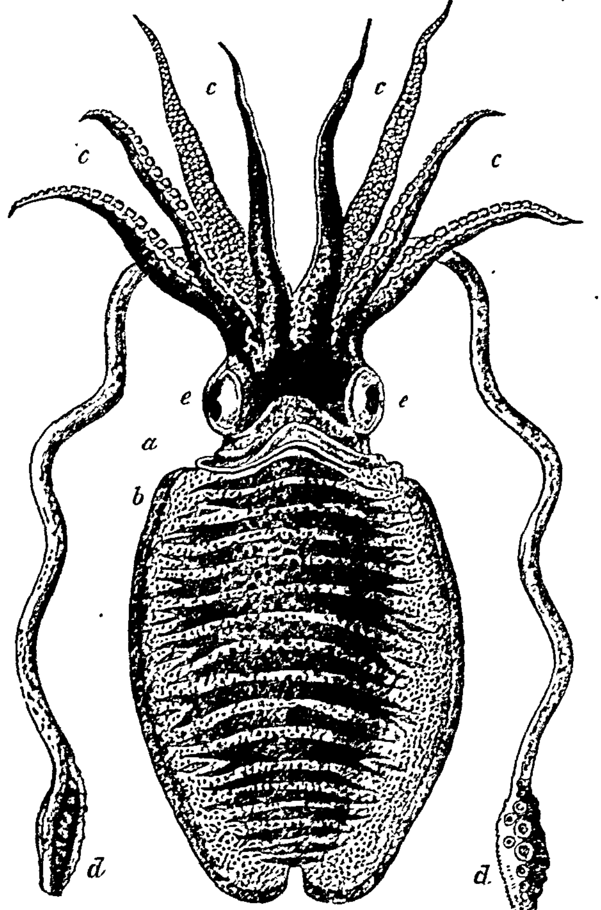

FIG. 92.—*Sepia officinalis*, L., half the natural size, as seen when dead, the long prehensile arms being withdrawn from the pouches at the side of the head, in which they are carried during life when not actually in use. *a*, neck; *b*, lateral fin of the mantle-sac; *c*, the eight shorter arms of the fore-foot; *d*, the two long prehensile arms; *e*, the eyes.

a single pair of nephridia opening by apertures right and left of the median anus (fig. 103, *r*), and by similar internal pores into the pericardial chamber, which consequently does not open directly to the surface as in Nautilus. The oviducts are sometimes paired right and left (Octopoda), sometimes that of one side only is developed (Decapoda, except Ommastrephes). The sperm-duct is always single except, according to Keferstein, in *Eledone moschata.*

A plate-like shell is developed in a closed sac formed by the mantle (figs. 98, 99), except in the Octopoda, which have none, and in Spirula (fig. 100, D) and the extinct Belemnitidæ, which have a small chambered shell resembling that of Nautilus with or without the addition of plate-like and cylindrical accessory developments (fig. 100, C).

The pair of cephalic eyes are highly-developed vesicles with a refractive lens (fig. 120), cornea, and lid-folds,—the vesicle being in the embryo an open sac like that of Nautilus (fig. 119). Osphradia are not present, but cephalic olfactory organs are recognized. One or two pairs of large salivary glands with long ducts are present. An ink-sac formed as a diverticulum of the rectum and opening near the anus is present in all Dibranchiata (fig. 103, *t*), and has been detected even in the fossil Belemnitidæ. Branchial hearts are developed on the two branchial advehent blood-vessels (fig. 104, *vc'*, *vi*).

The Dibranchiata are divisible into two sub-orders, according to the number and character of the arm-like sucker-bearing processes of the fore-foot.

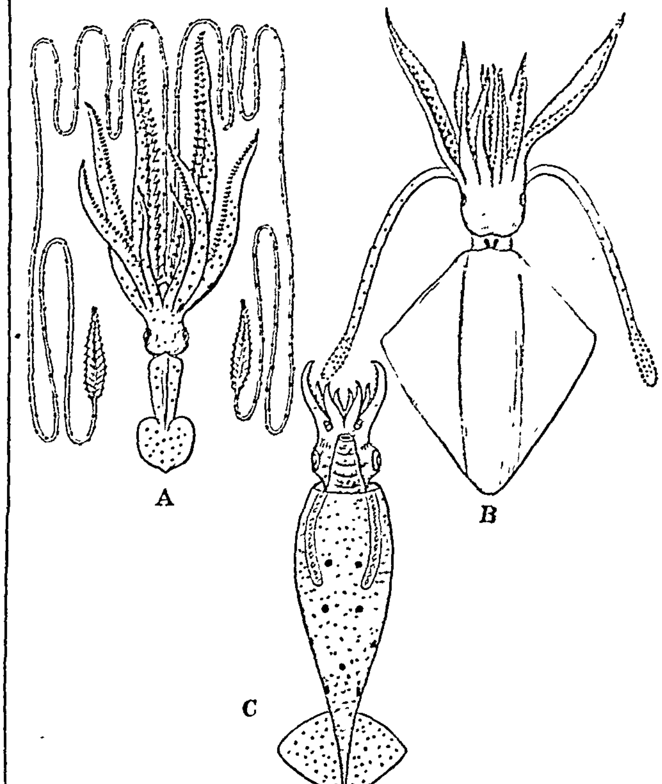

FIG. 93.—Decapodous Siphonopods; one-fourth the natural size linear. A. *Cheiroteuthis Veranyi*, d'Orb. (from the Mediterranean) B. *Thysanoteuthis rhombus*, Troschel (from Messina). C. *Loligopsis cyclura*, Fér. and d'Orb. (from the Atlantic Ocean).

Sub-order 1.—*Decapoda.*

Characters.—Dibranchiata with the fore-foot drawn out into eight shorter and two longer arms (prehensile arms), the latter being placed right and left between the third and fourth shorter arms. The suckers are stalked and strengthened by a horny ring. The eyes are large and have a horizontal in place of a sphincter-like lid. The body is elongated and provided with lateral fins (lamelliform expansions of the mantle). The mouth has a buccal membrane. The mantle-margin is locked to the base of the siphon by a specially-developed cartilaginous apparatus. Numerous water-pores are present in the head and anterior region of the body, leading into recesses of the integument of unknown significance. The oviduct is single; large nidamental glands are present. The viscero-pericardial space is large, and lodges the ovary (Sepia). There is always a shell present which is enclosed by the upgrowth of the mantle, so as to become "internal."

Section *a.*—*Decapoda Calciphora.*

Character.—Internal shell calcareous.
Family 1.—*Spirulidæ.*
Genus: *Spirula*, Lam. (fig. 100, D).
Family 2.—*Belemnitidæ.*
Genera: [*Spirulirostra*], d'Orb. (fig. 100, C); [*Beloptera*], Desh.; [*Belemnosis*], Edw.; [*Conoteuthis*], d'Orb. (fig. 100, A); [*Acanthoteuthis*], R. Wag.; [*Belemnites*], Lister, 1678; [*Belemnitella*], d'Orb.; [*Xiphoteuthis*], Huxley.
Family 3.—*Sepiadæ.*
Genera: *Sepia*, L. (figs. 92, 93, &c.); [*Belosepia*], Voltz; *Coccoteuthis*, Owen.

Family 1.—*Nautilidæ.*
Genera: [*Orthoceras*], Breyn.; [*Cyrtoceras*], Goldfuss; [*Gomphoceras*], Münster; [*Phragmoceras*], Brod.; [*Gyroceras*], Meyer; [*Ascoceras*], Barraude; [*Oncoceras*], Hall; [*Lituites*], Breyn.; [*Trochoceras*], Barraude; *Nautilus*, L. (figs. 88, 89, 90, &c.); [*Clymenia*], Münst.; [*Nothoceras*], Barraude.
Family 2.—*Ammonitidæ.*
Genera: [*Bactrites*], Sanderg.; [*Goniatites*], de Haan; [*Rhabdoceras*], Hauer; [*Clydonites*], Hauer; [*Cochloceras*], Hauer; [*Baculina*], d'Orb.; [*Ceratites*], de Haan; [*Baculites*], Lam.; [*Toxoceras*], d'Orb.; [*Crioceras*], Leveillé; [*Ptychoceras*], d'Orb.; [*Hamites*], Parkinson; [*Ancyloceras*], d'Orb.; [*Scaphites*], Parkinson; [*Ammonites*], Breyn.; [*Turrilites*], Lam.; [*Helioceras*], d'Orb.; [*Heteroceras*], d'Orb.
N.B.—The names in brackets are those of extinct genera.

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Characters.—Siphonopodous Cephalopods in which the inflected lateral margins of the mid-foot are fused so as to form a complete tubular siphon (fig. 96, *i*). The circumoral lobes of the fore-foot carry suckers disposed upon them in rows (as in the Pteropod Pneumodermon), *not* tentacles (see figs. 92, 95, 96). There is a single pair of typical ctenidia (fig. 103) acting as gills (hence Dibranchiata), and

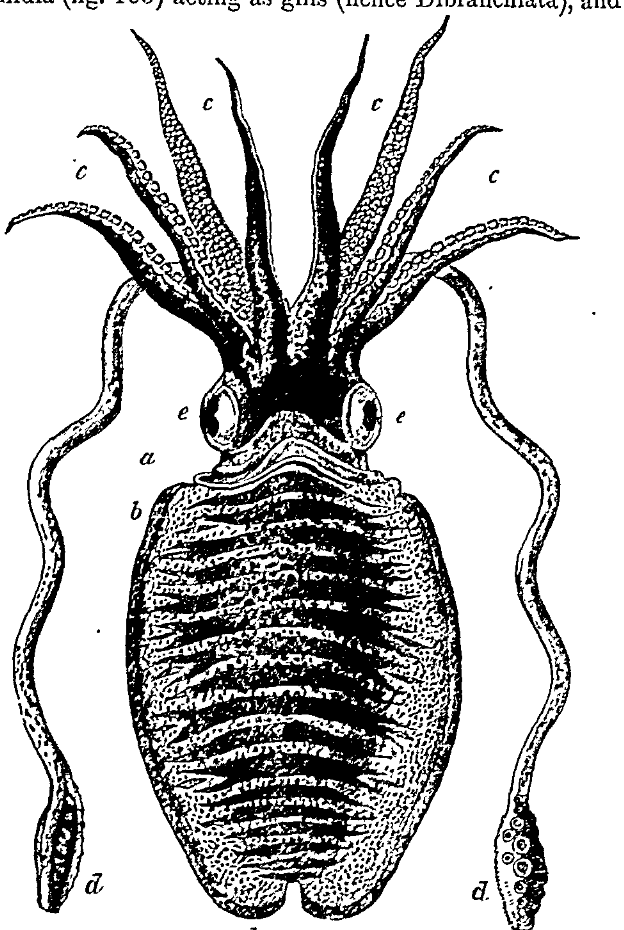

FIG. 92.—*Sepia officinalis*, L., half the natural size, as seen when dead, the long prehensile arms being withdrawn from the pouches at the side of the head, in which they are carried during life when not actually in use. *a*, neck; *b*, lateral fin of the mantle-sac; *c*, the eight shorter arms of the fore-foot; *d*, the two long prehensile arms; *e*, the eyes.

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The pair of cephalic eyes are highly-developed vesicles with a refractive lens (fig. 120), cornea, and lid-folds,—the vesicle being in the embryo an open sac like that of Nautilus (fig. 119). Osphradia are not present, but cephalic olfactory organs are recognized. One or two pairs of large salivary glands with long ducts are present. An ink-sac formed as a diverticulum of the rectum and opening near the anus is present in all Dibranchiata (fig. 103, *t*), and has been detected even in the fossil Belemnitidæ. Branchial hearts are developed on the two branchial advehent blood-vessels (fig. 104, *vc′*, *vi*).

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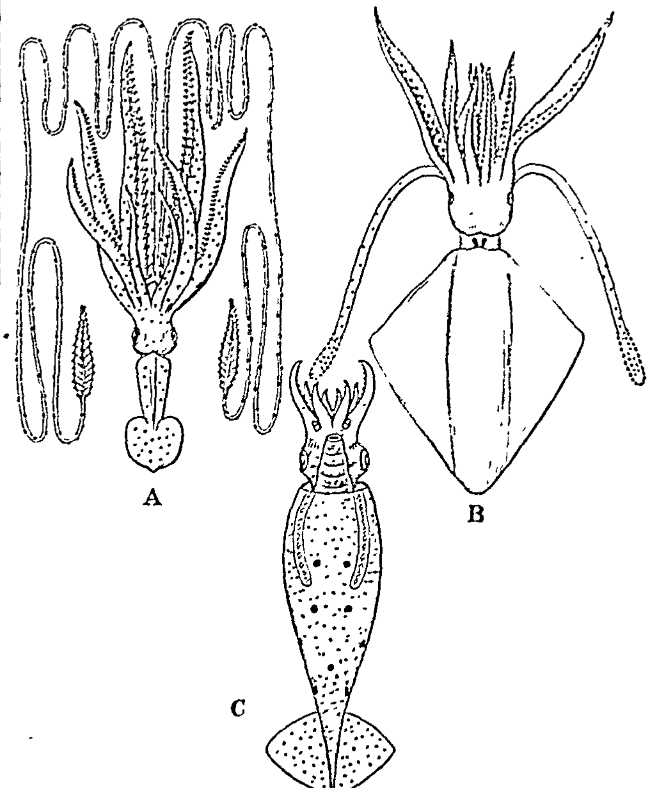

FIG. 93.—Decapodous Siphonopods; one-fourth the natural size linear. A. *Cheiroteuthis Veranyi*, d'Orb. (from the Mediterranean) B. *Thysanoteuthis rhombus*, Troschel (from Messina). C. *Loligopsis cyclura*, Fér. and d'Orb. (from the Atlantic Ocean).

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Family 3.—*Sepiadæ.*
Genera: *Sepia*, L. (figs. 92, 98, &c.); [*Belosepia*], Voltz; *Coccoteuthis*, Owen.

body. Amongst Gastropods it is not very unusual to find the animal slipping forward in its shell as growth advances and leaving an unoccupied chamber in the apex of the shell. This may indeed become shut off from the occupied cavity by a transverse septum, and a series of such septa may be formed (fig. 42), but in no Gastropod are these apical chambers known to contain a gas during the life of the animal in whose shell they occur. A further peculiarity of the Nautilus shell and of that of the allied extinct Ammonites, Scaphites, Orthoceras, &c., and of the living Spirula, is that the series of deserted air-chambers are traversed by a cord-like pedicle extending from the centro-dorsal area of the visceral hump to the smallest and first-formed chamber of the series. No structure comparable to this siphuncular pedicle is known in any other Mollusca. Its closest representative is found in the so-called "contractile cord" of the remarkable form Rhabdopleura, referred according to present knowledge to the Polyzoa. There appears to be no doubt that the deserted chambers of the Nautilus shell contain in the healthy living animal a gas which serves to lessen the specific gravity of the whole organism. The gas is said to be of the same composition as the atmosphere, with a larger proportion of nitrogen. With regard to its origin we have only conjectures. Each septum shutting off an air-containing chamber is formed during a period of quiescence, probably after the reproductive act, when the visceral mass of the Nautilus may be slightly shrunk, and gas is secreted from the dorsal integument so as to fill up the space previously occupied by the animal. A certain stage is reached in the growth of the animal when no new chambers are formed. The whole process of the loosening of the animal in its chamber and of its slipping forward when a new septum is formed, as well as the mode in which the air-chambers may be used as a hydrostatic apparatus, and the relation to this use, if any, of the siphuncular pedicle, is involved in obscurity, and is the subject of much ingenious speculation. In connexion with the secretion of gas by the animal, besides the parallel cases ranging from the Protozoon Arcella to the Physoclistic Fishes, from the Hydroid Siphonophora to the insect-larva Corethra, we have the identical phenomenon observed in the closely-allied Sepia when recently hatched. Here, in the pores of the internal rudimentary shell, gas is observable, which has necessarily been liberated by the tissues which secrete

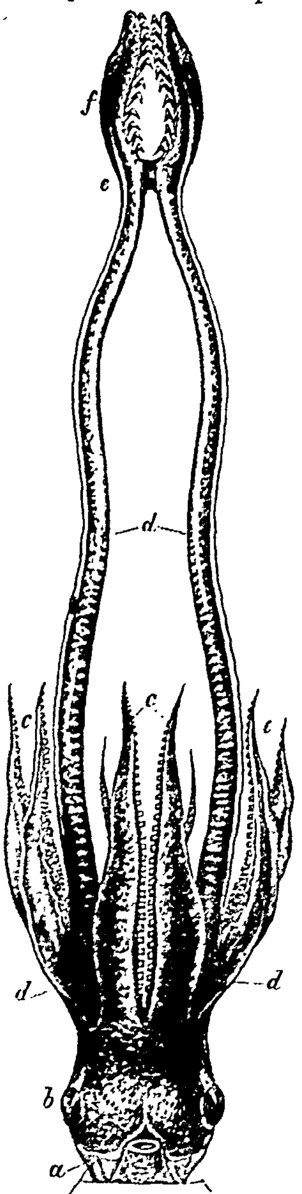

FIG. 97.—Head and circum-oral processes of the fore-foot of Onychoteuthis (from Owen). *a*, neck; *b*, eye; *c*, the eight short arms; *d*, long prehensile arms, the clavate extremities of which are provided with suckers at *e*, and with a double row of hooks beyond at *f*. The temporary conjunction of the arms by means of the suckers enables them to act in combination.

the shell, and not derived from any external source (Huxley).

The coiled shell of Nautilus, and by analogy that of the Ammonites, is peculiar in its relation to the body of the animal, inasmuch as the curvature of the coil proceeding

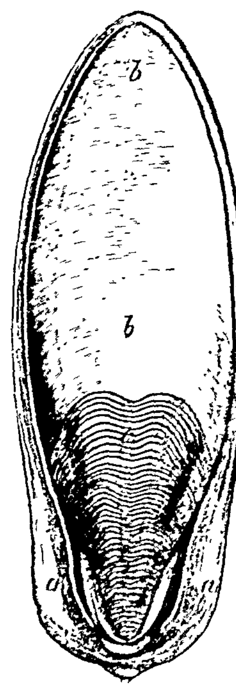

Fig. 98.

Fig. 99.

FIG. 98.—The calcareous internal shell of *Sepia officinalis*, the so-called cuttle-bone. *a*, lateral expansion; *b*, anterior cancellated region; *c*, laminated region, the laminæ enclosing air.
FIG. 99.—The horny internal shell or gladius or pen of Loligo.

from the centro-dorsal area is towards the head or forward, instead of away from the head and backwards as in other discoid coiled shells such as Planorbis; the coil is in fact absolutely reversed in the two cases. Amongst the extinct allies of the Nautilus (Tetrabranchiata) we find shells of a variety of shapes, open coils such as Scaphites, leading on to perfectly cylindrical shells with chamber succeeding chamber in a straight line (Orthoceras), whence again we may pass to the cork-screw spires formed by the shell of Turrilites.

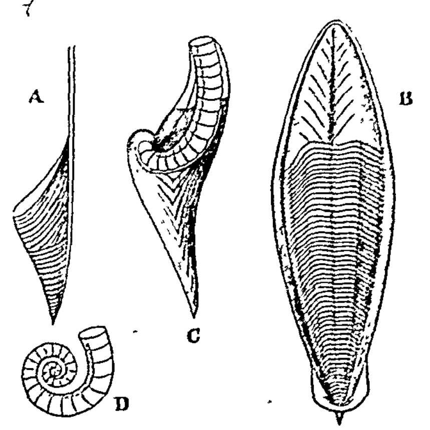

FIG. 100.—Internal shells of Cephalopoda Siphonopoda. A. Shell of *Conoteuthis dupiniana*, d'Orb. (from the Neocomian of France) B. Shell of *Sepia orbigniana*, Fér. (Mediterranean). C. Shell of *Spirulirostra Bellardii*, d'Orb. (from the Miocene of Turin). The specimen is cut so as to show in section the chambered shell and the laminated "guard" deposited upon its surface. D. Shell of *Spirula lævis*, Gray (New Zealand).

Whilst the Tetrabranchiata, so far as we can recognize their remains, are characterized by these large chambered shells, which, as in Nautilus, were with the exception of some narrow-mouthed forms such as Gomphoceras but very partially covered by reflexions of the mantle-skirt (fig. 89, *b*), the Dibranchiata present an interesting series of gradations, in which we trace—(*a*) the diminution in relative size of the chambered shell; (*b*) its complete investiture by reflected folds of the mantle (S[illegible] fig. 100, D); (*c*) the concrescence

body. Amongst Gastropods it is not very unusual to find the animal slipping forward in its shell as growth advances and leaving an unoccupied chamber in the apex of the shell. This may indeed become shut off from the occupied cavity by a transverse septum, and a series of such septa may be formed (fig. 42), but in no Gastropod are these apical chambers known to contain a gas during the life of the animal in whose shell they occur. A further peculiarity of the Nautilus shell and of that of the allied extinct Ammonites, Scaphites, Orthoceras, &c., and of the living Spirula, is that the series of deserted air-chambers are traversed by a cord-like pedicle extending from the centro-dorsal area of the visceral hump to the smallest and first-formed chamber of the series. No structure comparable to this siphuncular pedicle is known in any other Mollusca. Its closest representative is found in the so-called "contractile cord" of the remarkable form Rhabdopleura, referred according to present knowledge to the Polyzoa. There appears to be no doubt that the deserted chambers of the Nautilus shell contain in the healthy living animal a gas which serves to lessen the specific gravity of the whole organism. The gas is said to be of the same composition as the atmosphere, with a larger proportion of nitrogen. With regard to its origin we have only conjectures. Each septum shutting off an air-containing chamber is formed during a period of quiescence, probably after the reproductive act, when the visceral mass of the Nautilus may be slightly shrunk, and gas is secreted from the dorsal integument so as to fill up the space previously occupied by the animal. A certain stage is reached in the growth of the animal when no new chambers are formed. The whole process of the loosening of the animal in its chamber and of its slipping forward when a new septum is formed, as well as the mode in which the air-chambers may be used as a hydrostatic apparatus, and the relation to this use, if any, of the siphuncular pedicle, is involved in obscurity, and is the subject of much ingenious speculation. In connexion with the secretion of gas by the animal, besides the parallel cases ranging from the Protozoon Arcella to the Physoclistic Fishes, from the Hydroid Siphonophora to the insect-larva Corethra, we have the identical phenomenon observed in the closely-allied Sepia when recently hatched. Here, in the pores of the internal rudimentary shell, gas is observable, which has necessarily been liberated by the tissues which secrete the shell, and not derived from any external source (Huxley).

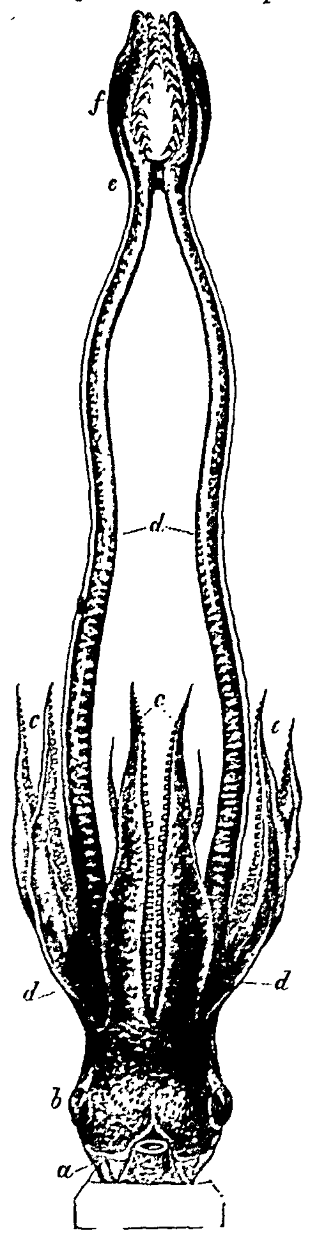

Fig. 97.—*Head and circum-oral processes of the fore-foot of Onychoteuthis (from Owen). a, neck; b, eye; c, the eight short arms; d, long prehensile arms, the clavate extremities of which are provided with suckers at e, and with a double row of hooks beyond at f. The temporary conjunction of the arms by means of the suckers enables them to act in combination.*

The coiled shell of Nautilus, and by analogy that of the Ammonites, is peculiar in its relation to the body of the animal, inasmuch as the curvature of the coil proceeding from the centro-dorsal area is towards the head or forward, instead of away from the head and backwards as in other discoid coiled shells such as Planorbis; the coil is in fact absolutely reversed in the two cases. Amongst the extinct allies of the Nautilus (Tetrabranchiata) we find shells of a variety of shapes, open coils such as Scaphites, leading on to perfectly cylindrical shells with chamber succeeding chamber in a straight line (Orthoceras), whence again we may pass to the cork-screw spires formed by the shell of Turrilites.

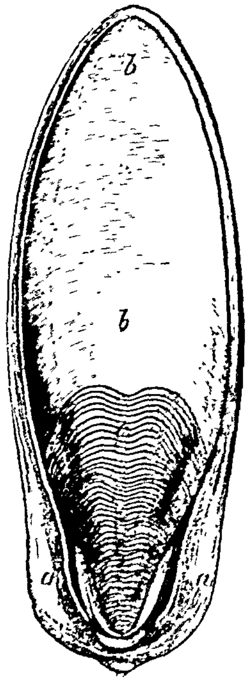

Fig. 98.

Fig. 99.

Fig. 98.—The calcareous internal shell of *Sepia officinalis*, the so-called cuttle-bone. *a*, lateral expansion; *b*, anterior cancellated region; *c*, laminated region, the laminæ enclosing air.
Fig. 99.—The horny internal shell or gladius or pen of Loligo.

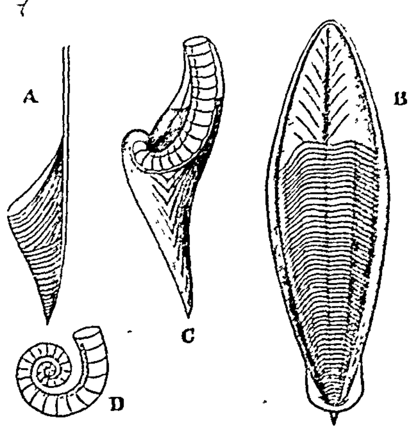

Fig. 100.—Internal shells of Cephalopoda Siphonopoda. A. Shell of *Conoteuthis dupiniana*, d'Orb. (from the Neocomian of France) B. Shell of *Sepia orbigniana*, Fér. (Mediterranean). C. Shell of *Spirulirostra Bellardii*, d'Orb. (from the Miocene of Turin). The specimen is cut so as to show in section the chambered shell and the laminated "guard" deposited upon its surface. D. Shell of *Spirula lævis*, Gray (New Zealand).

Whilst the Tetrabranchiata, so far as we can recognize their remains, are characterized by these large chambered shells, which, as in Nautilus, were with the exception of some narrow-mouthed forms such as Gomphoceras but very partially covered by reflexions of the mantle-skirt (fig. 89, *b*), the Dibranchiata present an interesting series of gradations, in which we trace—(*a*) the diminution in relative size of the chambered shell; (*b*) its complete investiture by reflected folds of the mantle (S[illegible] fig. 100, D); (*c*) the concrescence

sac opens by a pore into each nephridium instead of directly to the surface. A single pair of ctenidia (gill-plumes) is present instead of the two pairs in Nautilus. The existence of two pairs of ctenidia and of two pairs of nephridia in Nautilus, placed one behind the other, is highly remarkable. The interest of this arrangement is in relation to the general morphology of the Mollusca, for it is impossible to view this repetition of organs in a linear series as anything else than an instance of metameric segmentation, comparable to the segmentation of the ringed worms and Arthropods. The only other example which we have of this metamerism in the Mollusca is presented by the Chitons. There we find not two pairs of ctenidia merely, but sixteen pairs (in some species more) accompanied by a similar metamerism of the dorsal integument, which carries eight shells. In Chiton the nephridia are not affected by the metamerism as they are in Nautilus. It is impossible on the present occasion to discuss in the way which their importance demands the significance of these two instances among Mollusca of incomplete or partial metamerism; but it would be wrong to pass them by without insisting upon the great importance which the occurrence of these isolated instances of metameric segmentation in a group of otherwise unsegmented organisms possesses, and the light which they may be made to throw upon the nature of metameric segmentation in general.

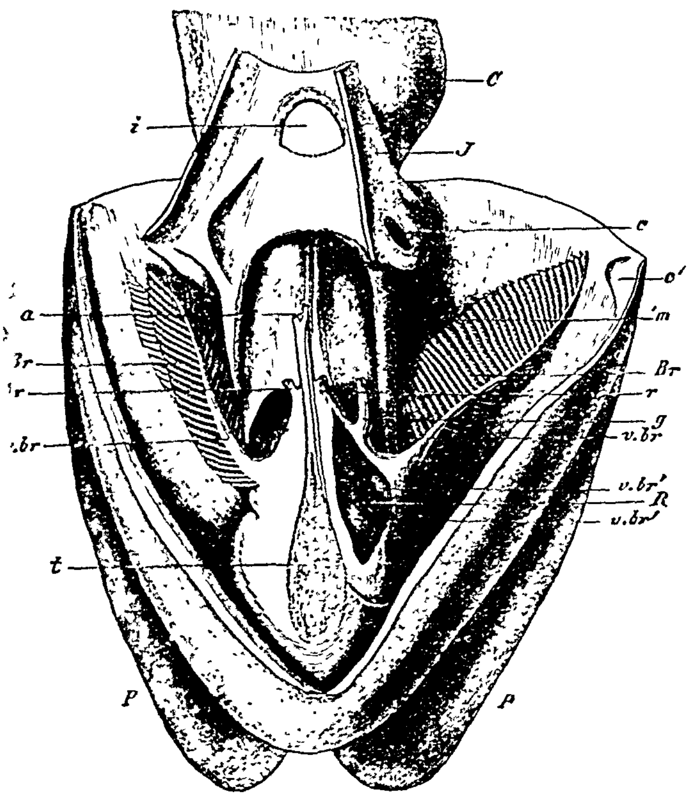

FIG. 103.—View of the postero-ventral surface of a male Sepia, obtained by cutting longitudinally the firm mantle-skirt and drawing the divided halves apart. This figure is strictly comparable with fig. 101. *C*, the head; *J*, the *mid-foot or siphon*, which has been cut open so as to display the valve *i*; *R*, the glandular tissue of the left nephridium or renal-sac, which has been cut open (see fig. 108); *P*, *P*, the lateral fins of the mantle-skirt; *Br*, the single pair of branchiæ (ctenidia); *a*, the anus,—immediately below it is the opening of the ink-bag; c, cartilaginous socket in the siphon to receive *c′*, the cartilaginous knob of the mantle-skirt,—the two constituting the "pallial hinge apparatus" characteristic of Decapoda, not found in Octopoda; *g*, the azygos genital papilla and aperture; *′i*, valve of the siphon (possibly the rudimentary hind-foot); *m*, muscular band connected with the fore-foot and mid-foot (siphon) and identical with the muscular mass *k* in fig. 91; *r*, renal papillæ, carrying the apertures of the nephridia; *v.br*, branchial efferent blood-vessel; *v.br′*, bulbous enlargements of the branchial blood vessels (see figs. 104, 108); *t*, ink-bag. (From Gegenbaur.)

The foot and head of Nautilus are in the adult inextricably grown together, the eye being the only part belonging primarily to the head which projects from the all-embracing foot. The fore-foot or front portion of the foot in Nautilus has the form of a number of lobes carrying tentacles and completely surrounding the mouth (figs. 88, 89, 91). The mid-foot is a broad median muscular process which exhibits in the most interesting manner a curling in of its margins so as to form an incomplete siphon (fig. 101), a condition which is completed and rendered permanent in the tubular funnel, which is the form presented by the corresponding part of Dibranchiata (fig. 96). The hind-foot possibly is represented by the valvular fold on the surface of the siphon-like mid-foot. In the Pteropoda the wing-like swimming lobes (epipodia or pteropodia) correspond to the two halves of the siphon, and are much the largest element of the foot. The fore-foot surrounding the head is often quite small, but in Clione and Pneumodermon carries lobes and suckers. A hind-foot is in Pteropoda often distinctly present; it is open to doubt as to whether the corresponding region of the foot in Siphonopoda is developed at all.

The lobes of the fore-foot of Nautilus and of the other Siphonopoda require further description. It has been doubted whether these lobes were rightly referred (by Huxley) to the fore-foot, and it has been maintained by some zoologists (Grenacher, Jhering) that they are truly processes of the head. It appears to the present writer to be impossible to doubt that the lobes in question are the fore-portion of the foot when their development is examined (see fig. 121, and especially fig. 72**), further, when the fact is considered that they are innervated by the pedal ganglion, and, lastly, when the comparison of such a Siphonopod as Sepia is made with such a Pteropod as Pneumodermon in its *larval* (fig. 84) as well as in its adult condition (fig. 85). The

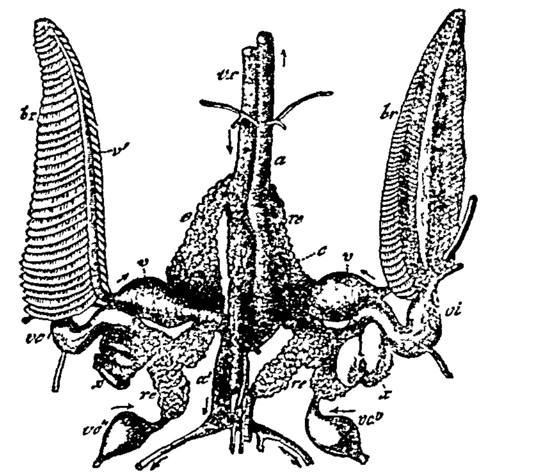

FIG. 104.—Circulatory and excretory organs of Sepia (from Gegenbaur, after John Hunter). *br*, branchiæ (ctenidia); *c*, ventricle of the heart; *a*, anterior artery (aorta); *a′*, posterior artery; *v*, the right and left auricles (enlargements of the efferent branchial veins); *v′*, efferent branchial vein on the free face of the gill-plume; *v.c*, vena cava; *vi*, *vc′*, advehent branchial vessels (branches of the vena cava, see fig. 108); *vc″*, abdominal veins; *x*, branchial hearts and appendages; *re*, *e*, glandular substance of the nephridia developed on the wall of the great veins on their way to the gills. The arrows indicate the direction of the blood-current.

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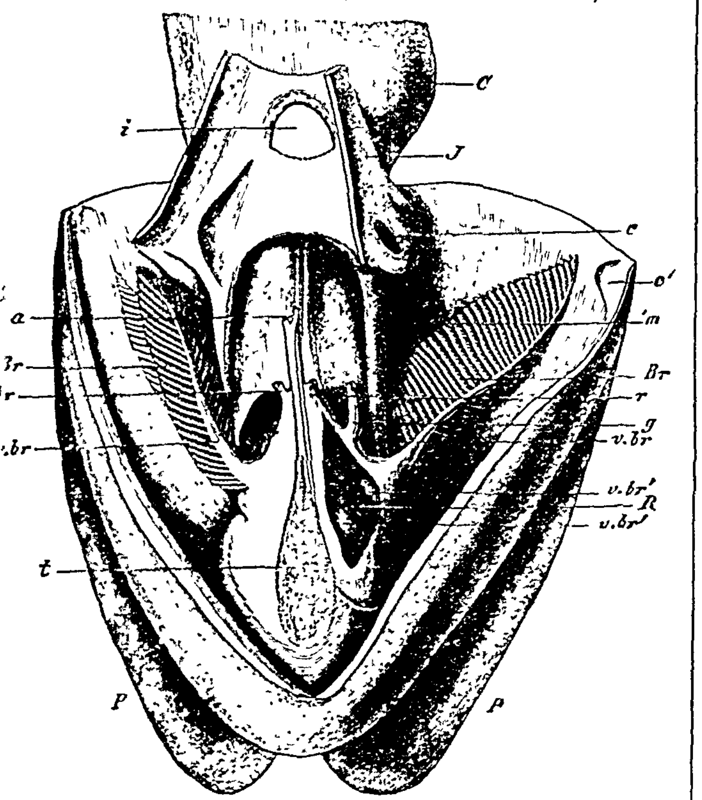

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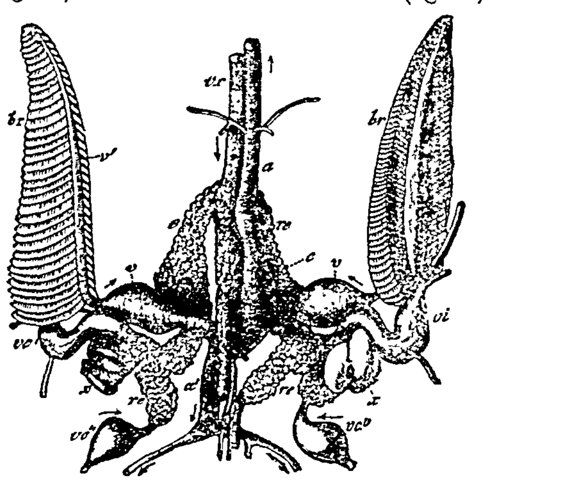

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Octopoda they are not unfrequently connected by a web, and form an efficient swimming-bell. The suckers are placed on the ad-oral surface of the arms, and may be in one, two, or four rows, and very numerous. In place of suckers in some genera we find on certain arms or parts of the arms horny hooks; in other cases a hook rises from the centre of each sucker. The hooks on the long arms of Onychoteuthis are drawn in fig. 97. The fore-foot, with its apparatus of suckers and hooks, is in the Dibranchiata essentially a prehensile apparatus, though the whole series of arms in the Octopoda serve as swimming organs, and in many (*e.g.*, the Common Octopus or Poulp) the sucker-bearing surface is used as a crawling organ.

In the males of the Dibranchiata one of the arms is more or less modified in connexion with the reproductive function, and is called the "hectocotylized arm." This name is derived from the condition assumed by the arm in those cases in which its modification is carried out to the greatest extent. These cases are those of the Octopods *Argonauta argo* and *Parasira catenulata* (fig. 96). In the males of these the third arm (on the left side in Argonauta, on the right side in Parasira) is found before the breeding season to be represented by a globular sac of integument. This sac bursts, and from it issues an arm larger than its neighbours, having a small sac at its extremity in Parasira (fig. 96, *x*), from which subsequently a long filament issues. Before copulation the male charges this arm with the spermatophores or packets of spermatozoa removed from its generative orifice beneath the mantle-skirt, and during coitus the arm becomes detached and is left adhering to the female by means of its suckers. A new arm is formed at the cicatrix before the next breeding season. The female, being much larger than the male, swims away with the detached arm lodged beneath her mantle-skirt. There, in a way which is not understood, the fertilization of the eggs is effected. Specimens of the female Parasira with the detached arm adherent were examined by Cuvier, who mistook the arm for a parasitic worm and gave to it the name Hectocotylus. Accordingly, the correspondingly modified arms of other Siphonopoda are said to be hectocotylized. Steenstrup has determined the hectocotylized condition of one or other of the arms in a number of male Dibranchs as follows:—in all, excepting Argonauta and Parasira, the modification of the arm is slight, consisting in a small enlargement of part or the whole of the arm, and the obliteration of some of its suckers, as shown in fig. 95, A, B; in Octopus and Eledone the third right arm is hectocotylized; in Rossia the first left arm is hectocotylized along its whole length, and the first right arm also in the middle only; in Sepiola only the first left arm along its whole length; in Sepia it is the fourth left arm which is modified, and at its base only; in Sepioteuthis, the same at its apex; in Loligo, the same also at its apex; in Loliolus, the same along its whole length; in Ommastrephes, Onychoteuthis, and Loligopsis no hectocotylized arm has hitherto been observed.

In the females of several Dibranchs (Sepia, &c.) the packets of spermatozoa or spermatophores received from the male have been observed adhering to the smaller arms. How they are passed in this case by the female to the ova in order to fertilize them is unknown.

Musculature, Fins, and Cartilaginous Skeleton.—Without entering into a detailed account of the musculature of Nautilus, we may point out that the great muscular masses of the fore-foot and of the mid-foot (siphon) are ultimately traceable to a large transverse mass of muscular tissue, the ends of which are visible through the integument on the right and left surfaces of the body dorsal of the free flap of the mantle-skirt (fig. 89, *l*, *l*, and fig. 91, *k*). These muscular areæ have a certain adhesion to the shell, and serve both to hold the animal in its shell and as the fixed supports for the various movements of the tentaculiferous lobes and the siphon. They are to be identified with the ring-like area of adhesion by which the foot-muscle of the Limpet is attached to the shell of that animal (see fig. 27). In the Dibranchs a similar origin of the muscular masses of the fore-foot and mid-foot from the sides of the shell—modified, as this is, in position and relations—can be traced.

In Nautilus there are no fin-like expansions of the integument, whereas such occur in the Decapod Dibranchs along the sides of the visceral hump (figs. 92, 93). As an exception among Octopoda lateral fins occur in Pinnoctopus (fig. 94, A), and in Cirrhoteuthis (fig. 94, D). In the Pteropodous division of the Cephalopoda such fin-like expansions of the dorsal integument do not occur, which is to be connected with the fact that another region, the mid-foot, which in Siphonopods is converted into a siphon, is in them expanded as a pair of fins.

In Nautilus there is a curious plate-like expansion of integument in the mid-dorsal region just behind the hood, lying between that structure and the portion of mantle-skirt which is reflected over the shell. This is shown in fig. 90, *b*. If we trace out the margin of this plate we find that it becomes continuous on each side with the sides of the siphon or mid-foot. In Sepia and other Decapods (not in Octopods) a closely similar plate exists in an exactly corresponding position (see *b* in figs. 110, 111). In Sepia a cartilaginous development occurs here immediately below the integument forming the so-called "nuchal plate," drawn in fig. 116, D. The morphological significance of this nuchal lamella, as seen both in Nautilus and in Sepia, is not obvious. Cartilage having the structure shown in fig. 117 occurs in various regions of the body of Siphonopoda. In all Glossophorous Mollusca the lingual apparatus is supported by internal skeletal pieces, having the character of cartilage; but in the Siphonopodous Cephalopoda such cartilage has a wider range.

In Nautilus a large H-shaped piece of cartilage is found forming the axis of the mid-foot or siphon (fig. 116, A, B). Its hinder part extends up into the head and supports the peri-œsophageal nerve-mass (*a*), whilst its two anterior rami extend into the tongue-like siphon. In Sepia, and Dibranchs generally, the cartilage takes a different form, as shown in fig. 116, C. The processes of this cartilage cannot be identified in any way with those of the capito-pedal cartilage of Nautilus. The lower larger portion of this cartilage in Sepia is called the cephalic cartilage, and forms a complete ring round the œsophagus; it completely invests also the ganglionic nerve-collar, so that all the nerves from the latter have to pass through foramina in the cartilage. The outer angles of this cartilage spread out on each side so as to form a cup-like receptacle for the eyes. The two processes springing right and left from this large cartilage in the median line (fig. 116, C) are the "præ-orbital cartilages;" in front of these, again, there is seen a piece like an inverted T, which forms a support to the base of the "arms" of the fore-foot, and is the "basi-brachial" cartilage. The Decapod Dibranchs have, further, the "nuchal cartilage" already mentioned, and in Sepia, a thin plate-like "sub-ostracal" or (so-called) dorsal cartilage, the anterior end of which rests on and fits into the concave nuchal cartilage. In Octopoda there is no nuchal cartilage, but two band-like "dorsal cartilages." In Decapods there are also two cartilaginous sockets on the sides of the funnel —"siphon-hinge cartilages"—into which fleshy knobs of the mantle-skirt are loosely fitted. In Sepia, along the whole base-line of each lateral fin of the mantle (fig. 92), is a "basi-pterygial cartilage." It is worthy of remark that we have, thus developed, in Dibranch Siphonopods a more

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In Nautilus there are no fin-like expansions of the integument, whereas such occur in the Decapod Dibranchs along the sides of the visceral hump (figs. 92, 93). As an exception among Octopoda lateral fins occur in Pinnoctopus (fig. 94, A), and in Cirrhoteuthis (fig. 94, D). In the Pteropodous division of the Cephalopoda such fin-like expansions of the dorsal integument do not occur, which is to be connected with the fact that another region, the mid-foot, which in Siphonopods is converted into a siphon, is in them expanded as a pair of fins.

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In Nautilus a large H-shaped piece of cartilage is found forming the axis of the mid-foot or siphon (fig. 116, A, B). Its hinder part extends up into the head and supports the peri-œsophageal nerve-mass (*a*), whilst its two anterior rami extend into the tongue-like siphon. In Sepia, and Dibranchs generally, the cartilage takes a different form, as shown in fig. 116, C. The processes of this cartilage cannot be identified in any way with those of the capito-pedal cartilage of Nautilus. The lower larger portion of this cartilage in Sepia is called the cephalic cartilage, and forms a complete ring round the œsophagus; it completely invests also the ganglionic nerve-collar, so that all the nerves from the latter have to pass through foramina in the cartilage. The outer angles of this cartilage spread out on each side so as to form a cup-like receptacle for the eyes. The two processes springing right and left from this large cartilage in the median line (fig. 116, C) are the "præ-orbital cartilages;" in front of these, again, there is seen a piece like an inverted T, which forms a support to the base of the "arms" of the fore-foot, and is the "basi-brachial" cartilage. The Decapod Dibranchs have, further, the "nuchal cartilage" already mentioned, and in Sepia, a thin plate-like "sub-ostracal" or (so-called) dorsal cartilage, the anterior end of which rests on and fits into the concave nuchal cartilage. In Octopoda there is no nuchal cartilage, but two band-like "dorsal cartilages." In Decapods there are also two cartilaginous sockets on the sides of the funnel —"siphon-hinge cartilages"—into which fleshy knobs of the mantle-skirt are loosely fitted. In Sepia, along the whole base-line of each lateral fin of the mantle (fig. 92), is a "basi-pterygial cartilage." It is worthy of remark that we have, thus developed, in Dibranch Siphonopods a more

in relative size as the volume of the sac increases. Its outer surface acquires a metallic iridescence similar to that of the integuments of many fishes. The opening of the ink-sac is in the adult sometimes distinct from but near to

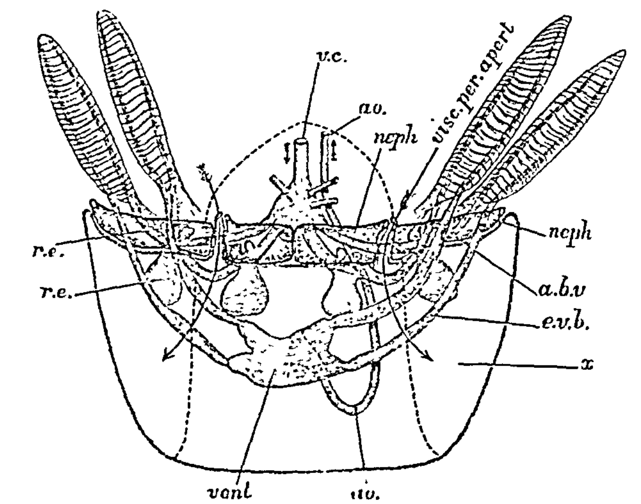

FIG. 109.—Diagram to show the relations of the four nephridial sacs, the viscero-pericardial sac, and the heart and large vessels in Nautilus (drawn by A. G. Bourne). *neph*, *neph*, on the right side point to the two nephridia of that side (the two of the opposite side are not lettered),—each is seen to have an independent aperture; *x* is the viscero-pericardial sac, the dotted line indicating its backward extension; *visc.per.apert* marks an arrow introduced into the right aperture of the viscero-pericardial sac; *r.e.*, *r.e.*, point to the glandular enlarged walls of the advehent branchial vessels,—two small glandular bodies of the kind are seen to project into each nephridial sac, whilst a larger body of the same kind depends from each of the four branchial advehent vessels into the viscero-pericardial sac; *v.c.*, vena cava; *vent*, ventricle of the heart; *ao.*, cephalic aorta (the small abdominal aorta not drawn); *a.b.v*, advehent branchial vessel; *e.v.b.*, efferent branchial vessel.

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Cœlom, Blood-vascular System, and Excretory Organs.—Nautilus and the other Siphonopoda conform to the

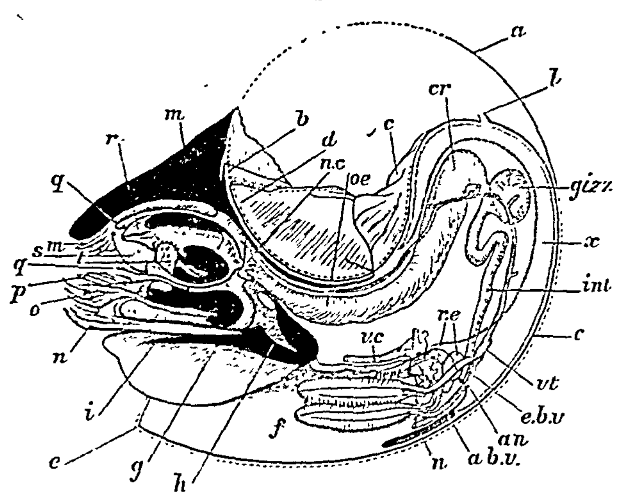
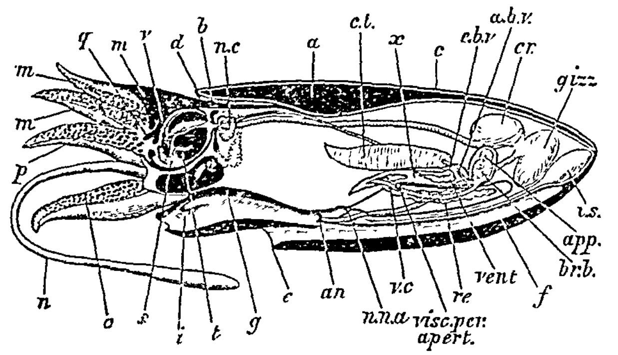


FIG. 110.—Diagram representing a vertical approximately median antero-posterior section of *Nautilus pompilius* (from a drawing by A. G. Bourne). The parts which are quite black are the cut muscular surfaces of the foot and buccal mass. *a*, the shell; *b*, the nuchal plate identical with the nuchal cartilage of Sepia (see fig. 90, *b*); *c*, the integument covering the visceral hump; *d*, the mantle flap or skirt in the dorsal region where it rests against the coil of the shell; *e*, the inferior margin of the mantle-skirt resting on the lip of the shell represented by the dotted line; *f*, the pallial chamber with two of the four gills; *g*, the vertically cut median portion of the mid-foot (siphon); *h*, the capito-pedal cartilage (see fig. 116); *i*, the valve of the siphon; *l*, the siphuncular pedicle (cut short); *m*, the hood or dorsal enlargement of the annular lobe of the fore-foot; *n*, tentacles of the annular lobe; *p*, tentacles of the inner inferior lobe; *q*, buccal membrane; *r*, upper jaw or beak; *s*, lower jaw or beak; *t*, lingual ribbon; *x*, the viscero-pericardial sac; *n.c*, nerve-collar; *oe*, œsophagus; *cr*, crop; *gizz*, gizzard; *int*, intestine; *an*, anus; *ni*, nidamental gland; *nept*, aperture of a nephridial sac; *r.e*, renal glandular masses on the walls of the afferent branchial veins (see fig. 109); *a.b.v.*, afferent branchial vessel; *e.b.v*, efferent branchial vessel; *vt*, ventricle of the heart.

general Molluscan characters in regard to these organs. Whilst the general body-cavity or cœlom forms a lacunar blood-system or series of narrow spaces, connected with the trunks of a well-developed vascular system, that part of the original cœlom surrounding the heart and known as the Molluscan pericardium becomes shut off from this general blood-lymph system, and communicates, directly in Nautilus, in the rest through the nephridia, with the exterior. In the Siphonopoda this specialized pericardial cavity is particularly large, and has been recognized as distinct from the blood-carrying spaces, even by anatomists who have not considered the pericardial space of other Mollusca to be thus isolated. The enlarged pericardium, which may even take the form of a pair of sacs, has been variously named, but is best known as the viscero-pericardial sac or chamber. In Nautilus this sac occupies the whole of the postero-dorsal surface and a part of the antero-dorsal (see fig. 110, *x*), investing the genital and other viscera which lie below it, and having the ventricle of the heart suspended in it. Certain membranes forming incomplete septa, and a curious muscular band—the pallio-cardiac band—traverse the sac. The four branchial advehent veins, which in traversing the walls of the four nephridial sacs give off, as it were, glandular diverticula into those sacs, also give off at the same points four much larger glandular



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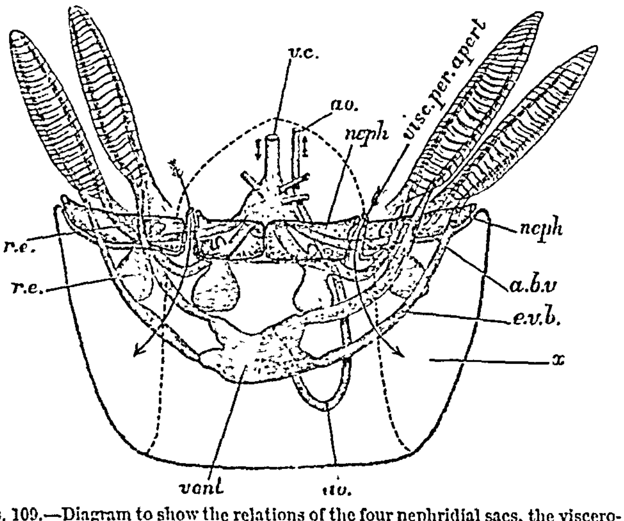

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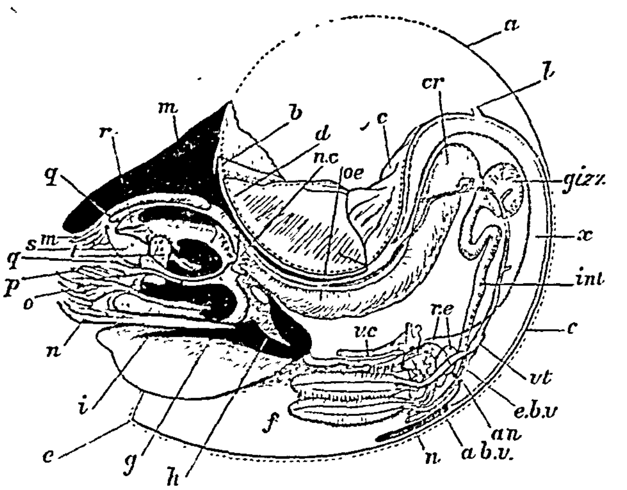

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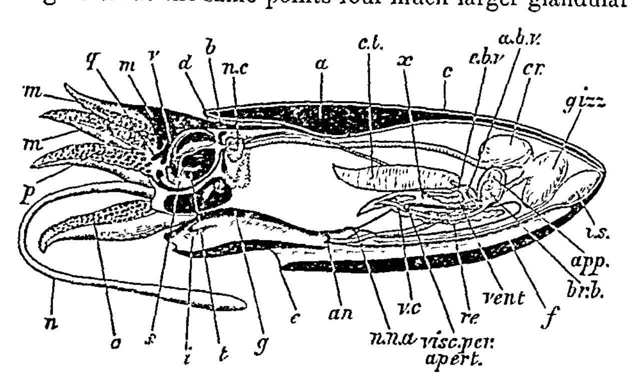

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of the two nephridia to form one sac is still more obvious, since the ventral portions are united. In Octopus the nephridia are quite separate.

Tegumental pores have not been described in Nautilus, but exist in Dibranchiata, and have been (probably erroneously, but further investigation is needed) supposed to introduce water into the vascular system. A pair of

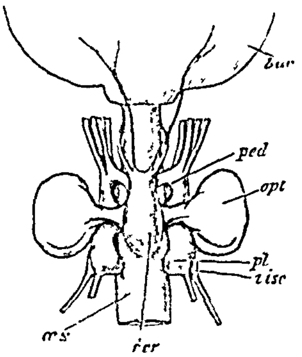

Fig. 113.

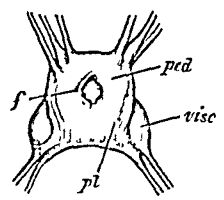

Fig. 114.

FIGS. 113, 114.—Nerve-centres of Octopus. Figure 113 gives a view from the dorsal aspect, figure 114 one from the ventral aspect. *buc*, the buccal mass; *ped*, pedal ganglion; *opt*, optic ganglion; *cer*, cerebral ganglion; *pl*, pleural ganglion; *visc*, visceral ganglion; *œs*, œsophagus; *f*, foramen in the nerve-mass formed by pedal, pleural, and visceral ganglion-pairs, traversed by a blood-vessel.

such pores leading into sub-tegumental spaces of considerable area, the nature of which is imperfectly known, exist on the back of the head in Philonexis, Tremoctopus, and Argonauta. At the base of the arms and mouth four such pores are found in Histioteuthis and Ommastrephes, six in Sepia, Loligo, Onychoteuthis. Lastly, a pair of such pores are found in the Decapoda at the base of the long arms, leading into an extensive sub-tegumental pouch on each side of the head into which the long arms can be, and usually are, withdrawn. In Sepia, Sepiola, and Rossia the whole arm is coiled up in these sacs; in Loligo only a part of it is so; in Histioteuthis, Ommastrephes, and Onychoteuthis, the sacs are quite small and do not admit the arms.

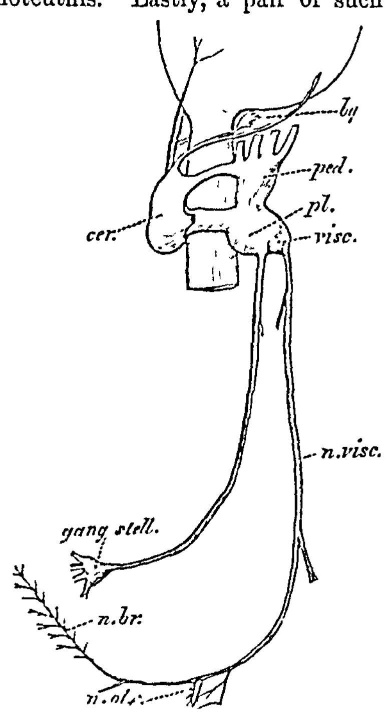

FIG. 115.—Lateral view of the nervous centres and nerves of the right side of *Octopus vulgaris* (from a drawing by A. G. Bourne). *bg*, buccal ganglion; *cer.*, cerebral ganglion; *ped.*, pedal ganglion; *pl.*, pleural, and *visc.*, visceral region of the pleuro-visceral ganglion; *gang. stell.*, the right stellate ganglion of the mantle connected by a nerve to the pleural portion; *n.visc.*, the right visceral nerve; *n.olf.*, its (probably) olfactory branches; *n.br.*, its branchial branches.

Nervous System.—Nautilus, like the other Cephalopoda (*e.g.*, Pneumodermon, fig. 87; Octopus, fig. 113), exhibits a great concentration of the typical Molluscan ganglia, as shown in fig. 112. The ganglia take on a band-like form, and are but little differentiated from their commissures and connectives,—an archaic condition reminding us of Chiton. The special optic outgrowth of the cerebral ganglion, the optic ganglion (fig. 112, *o*), is characteristic of the big-eyed Siphonopoda. The cerebral ganglion-pair (*a*) lying above the œsophagus is connected with two sub-œsophageal ganglion-pairs of band-like form. The anterior of these is the pedal *b*, *b*, and supplies the fore-foot with nerves *t'*, *t*, as also the mid-foot (siphon). The hinder band is the visceral and pleural pair fused (compare fig. 112 with fig. 87, and especially with the typical Euthyneurous nervous system of Limnæus, fig. 22); from its pleural portion nerves pass to the mantle, from its visceral portion nerves to the branchiæ and genital ganglion (*d* in fig. 112), and in immediate connexion with the latter is a nerve to the osphradium or olfactory papilla. No buccal ganglia have been observed in Nautilus, nor has an enteric nervous system been described in this animal, though both attain a special development in the Dibranchiata. The figures (114 and 115) representing the nerve-centres of Octopus serve to exhibit the disposition of these parts in the Dibranchiata. The ganglia are more distinctly swollen than in Nautilus. In Octopus an infra-buccal ganglion-pair are present corresponding to the buccal ganglion-pair of Gastropoda. In Decapoda a supra-buccal ganglion-pair connected with these are also developed. Instead of the numerous radiating pallial nerves of Nautilus, we have in the Dibranchiata on each side (right and left) a large pleural erve passing from the pleural portion of the pleuro-visceral ganglion to the mantle, where it enlarges to form the stellate ganglion. From each stellate ganglion nerves radiate to supply the powerful muscles of the mantle-skirt. The nerves from the visceral portion of the pleuro-visceral ganglion have the same course as in Nautilus, but no osphradial papilla is present. An enteric nervous system is richly developed in the Dibranchiata, connected with the somatic nervous centres through the buccal ganglia, as in the Arthropoda through the stomato-gastric ganglia, and anastomosing with deep branches of the visceral nerves of the viscero-pleural ganglion-pair. It has been especially described by Hancock (39) in Ommastrephes. Upon the stomach it forms a single large and readily-detected gastric ganglion. It is questionable as to how far this and the "caval ganglion" formed in some Decapoda by branches of the visceral nerves which accompany the vena cava are to be considered as the equivalents of the "abdominal ganglion," which in a typical Gastropod nervous system lies in the middle of the visceral nerve-loop or commissure, having the right and left visceral ganglia on either side of it, separated by a greater or less length of visceral nerve-cord (see figs. 20, 21, 22). There can be little doubt that the enteric nervous system is much more developed in the Dibranchiata than in other Mollusca, and that it effects a fusion with the typical "visceral" cords more extensive than obtains even in Gastropoda, where such a fusion no doubt must also be admitted.

Special Sense-Organs.—Nautilus possesses a pair of osphradial papillæ (fig. 101, *olf*) corresponding in position and innervation to Spengel's organ placed at the base of the ctenidia (branchiæ) in all classes of Mollusca. This organ has not been detected in other Siphonopoda. In Pteropoda it is well developed as a single ciliated pit, although the ctenidia are in that group aborted (fig. 87, *Osp.*). Nautilus possesses other olfactory organs in the region of the head. Just below the eye is a small triangular process (not seen in our figures), having the structure of a shortened and highly-modified tentacle and sheath. By Valenciennes, who is followed by Keferstein, this is regarded as an olfactory organ. The large nerve which runs to this organ originates from the point of juncture of the pedal with the optic ganglion. The lamelliform organ upon the inner inferior tentacular lobe of Nautilus is possibly also olfactory in function. In Dibranchs behind the eye is a pit or open canal supplied by a nerve corresponding in origin to the olfactory nerve of Nautilus above mentioned.

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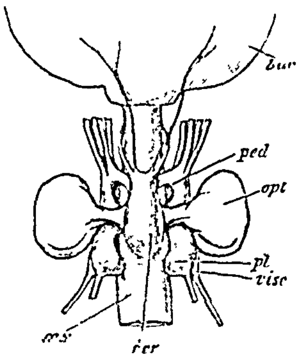

Fig. 113.

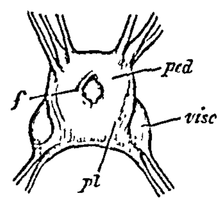

Fig. 114.

Figs. 113, 114.—Nerve-centres of Octopus. Figure 113 gives a view from the dorsal aspect, figure 114 one from the ventral aspect. *buc*, the buccal mass; *ped*, pedal ganglion; *opt*, optic ganglion; *cer*, cerebral ganglion; *pl*, pleural ganglion; *visc*, visceral ganglion; *œs*, œsophagus; *f*, foramen in the nerve-mass formed by pedal, pleural, and visceral ganglion-pairs, traversed by a blood-vessel.

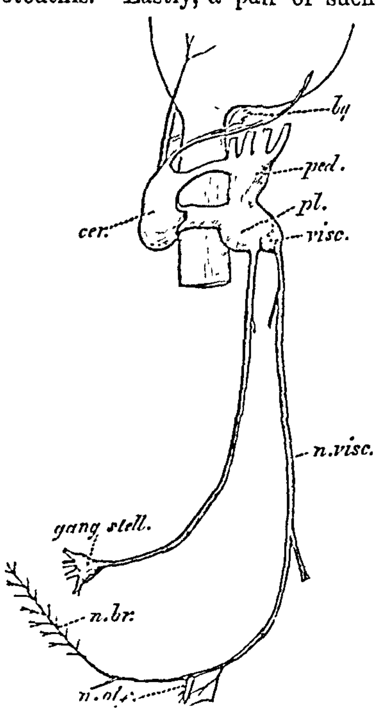

Fig. 115.—Lateral view of the nervous centres and nerves of the right side of *Octopus vulgaris* (from a drawing by A. G. Bourne). *bg*, buccal ganglion; *cer.*, cerebral ganglion; *ped.*, pedal ganglion; *pl.*, pleural, and *visc.*, visceral region of the pleuro-visceral ganglion; *gang. stell.*, the right stellate ganglion of the mantle connected by a nerve to the pleural portion; *n.visc.*, the right visceral nerve; *n.olf.*, its (probably) olfactory branches; *n.br.*, its branchial branches.

Nervous System.—Nautilus, like the other Cephalopoda (*e.g.*, Pneumodermon, fig. 87; Octopus, fig. 113), exhibits a great concentration of the typical Molluscan ganglia, as shown in fig. 112. The ganglia take on a band-like form, and are but little differentiated from their commissures and connectives,—an archaic condition reminding us of Chiton. The special optic outgrowth of the cerebral ganglion, the optic ganglion (fig. 112, *o*), is characteristic of the big-eyed Siphonopoda. The cerebral ganglion-pair (*a*) lying above the œsophagus is connected with two sub-œsophageal ganglion-pairs of band-like form. The anterior of these is the pedal *b*, *b*, and supplies the fore-foot with nerves *t'*, *t*, as also the mid-foot (siphon). The hinder band is the visceral and pleural pair fused (compare fig. 112 with fig. 87, and especially with the typical Euthyneurous nervous system of Limnæus, fig. 22); from its pleural portion nerves pass to the mantle, from its visceral portion nerves to the branchiæ and genital ganglion (*d* in fig. 112), and in immediate connexion with the latter is a nerve to the osphradium or olfactory papilla. No buccal ganglia have been observed in Nautilus, nor has an enteric nervous system been described in this animal, though both attain a special development in the Dibranchiata. The figures (114 and 115) representing the nerve-centres of Octopus serve to exhibit the disposition of these parts in the Dibranchiata. The ganglia are more distinctly swollen than in Nautilus. In Octopus an infra-buccal ganglion-pair are present corresponding to the buccal ganglion-pair of Gastropoda. In Decapoda a supra-buccal ganglion-pair connected with these are also developed. Instead of the numerous radiating pallial nerves of Nautilus, we have in the Dibranchiata on each side (right and left) a large pleural erve passing from the pleural portion of the pleuro-visceral ganglion to the mantle, where it enlarges to form the stellate ganglion. From each stellate ganglion nerves radiate to supply the powerful muscles of the mantle-skirt. The nerves from the visceral portion of the pleuro-visceral ganglion have the same course as in Nautilus, but no osphradial papilla is present. An enteric nervous system is richly developed in the Dibranchiata, connected with the somatic nervous centres through the buccal ganglia, as in the Arthropoda through the stomato-gastric ganglia, and anastomosing with deep branches of the visceral nerves of the viscero-pleural ganglion-pair. It has been especially described by Hancock (39) in Ommastrephes. Upon the stomach it forms a single large and readily-detected gastric ganglion. It is questionable as to how far this and the "caval ganglion" formed in some Decapoda by branches of the visceral nerves which accompany the vena cava are to be considered as the equivalents of the "abdominal ganglion," which in a typical Gastropod nervous system lies in the middle of the visceral nerve-loop or commissure, having the right and left visceral ganglia on either side of it, separated by a greater or less length of visceral nerve-cord (see figs. 20, 21, 22). There can be little doubt that the enteric nervous system is much more developed in the Dibranchiata than in other Mollusca, and that it effects a fusion with the typical "visceral" cords more extensive than obtains even in Gastropoda, where such a fusion no doubt must also be admitted.

Special Sense-Organs.—Nautilus possesses a pair of osphradial papillæ (fig. 101, *olf*) corresponding in position and innervation to Spengel's organ placed at the base of the ctenidia (branchiæ) in all classes of Mollusca. This organ has not been detected in other Siphonopoda. In Pteropoda it is well developed as a single ciliated pit, although the ctenidia are in that group aborted (fig. 87, *Osp.*). Nautilus possesses other olfactory organs in the region of the head. Just below the eye is a small triangular process (not seen in our figures), having the structure of a shortened and highly-modified tentacle and sheath. By Valenciennes, who is followed by Keferstein, this is regarded as an olfactory organ. The large nerve which runs to this organ originates from the point of juncture of the pedal with the optic ganglion. The lamelliform organ upon the *inner* inferior tentacular lobe of Nautilus is possibly also olfactory in function. In Dibranchs behind the eye is a pit or open canal supplied by a nerve corresponding in origin to the olfactory nerve of Nautilus above mentioned.

lens forms as a structureless growth, projecting inwards from the front wall of this vesicle (fig. 123, B, *l*). The integument around the primitive optic vesicle which has sunk below

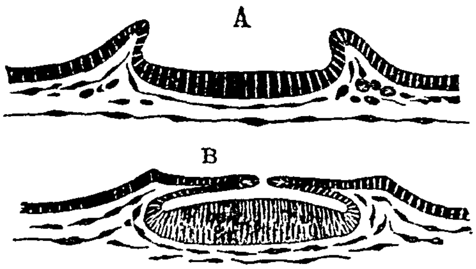

FIG. 119.—Diagrams of sections showing the early stage of development of the eye of Loligo when it is, like the permanent eye of Nautilus and of Patella, an open sac. A. First appearance of the eye as a ring-like upgrowth. B. Ingrowth of the ring-like wall so as to form a sac, the primitive optic vesicle of Loligo. (From Lankester.)

the surface now rises up and forms firstly nearest the axis of the eye the iridian folds (*if* in B, fig. 123; *ik* in fig. 120; *Ir in fig. 118), and then secondly an outer circular fold* grows up like a wall and completely closes over the iridian folds and the axis of the primitive vesicle (fig. 120, C). This covering is transparent, and is the cornea. In the oceanic Decapoda the cornea does not completely close, but leaves a central aperture traversed by the optic axis. These forms are termed Oigopsidæ by d'Orbigny (42), whilst the Decapoda with closed cornea are termed Myopsidæ. In the Octopoda the cornea is closed, and there is yet another fold thrown over the eye. The skin surrounding the cornea presents a free circular margin, and can be drawn over the surface of the cornea by a sphincter muscle. It thus acts as an adjustable diaphragm, exactly similar in

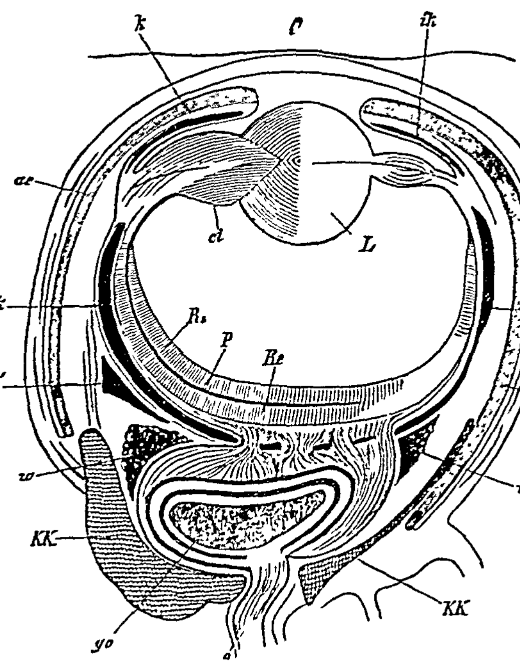

FIG. 120.—Horizontal section of the eye of Sepia (Myopsid). *KK*, cephalic cartilages (see fig. 116); *C*, cornea (closed); *L*, lens; *ci*, ciliary body; *Ri*, internal layer of the retina; *Re*, external layer of the retina; *p*, pigment between these; *o*, optic nerve; *go*, optic ganglion; *k* and *k'*, capsular cartilage; *ik*, cartilage of the iris; *w*, white body; *ae*, argentine integument. (From Gegenbaur, after Hensen.)

movement to the iris of Vertebrates. Sepia and allied Decapods have a horizontal lower eyelid, that is to say, only one-half of the sphincter-like fold of integument is movable. The exact history of the later growth of the lens in the Dibranchs' eye is not clear. As seen in fig. 120, it appears, after attaining a certain size, to push through the front wall of the primitive optic vesicle at the point corresponding to its centre of closure, and to project a little into the anterior chamber formed by the cornea. The wall of the primitive optic vesicle adjacent to the embedded lens (L) now becomes modified, forming a so-called "ciliary body," in which muscular tissue is present, serving to regulate the focus of the lens (*ci* in fig. 120). Bobretzky (43) differs from Lankester, whose view is above given, in assigning a distinct origin to the protruding anterior segment of the lens (l^1 in fig. 118). The optic ganglion, as well as the other large ganglia of the Dibranchiata, originate in the mesoblast of the embryo. The connexion between the cells of the retina and the nerve-fibres proceeding from the optic ganglion must therefore be a secondary one.

Chromatophores.—In Nautilus these remarkable structures, which we mention here as being intimately associated with the nervous system, appear to be absent. In Dibranchiata they play an important part in the economy, enabling their possessor, in conjunction with the discharge of the contents of the ink-bag, to elude the observation of either prey or foe. They consist of large vesicular cells (true nucleated cells converted into vesicles), arranged in *a layer immediately below the epidermis. Each chromatophore*-cell has from six to ten muscular bands attached to its walls, radiating from it star-wise. The contraction of these fibres causes the chromatophore-cell to widen out; it returns to its spherical resting state by its own elasticity. In the spherical resting state such a cell may measure ·01 mm., whilst when fully stretched by its radiating muscles it covers an area of ·5 mm. The substance of the chromatophore-cells is intensely coloured with one of the following colours—scarlet, yellow, blue, brown—which are usually of the greatest purity and brilliance. The action of the chromatophores may be watched most readily in young Loligo, either under the microscope or with the naked eye. The chromatophores are suddenly expanded, and more slowly retracted with rapidly-recurring alternation. All the blue, or all the red, or all the yellow may be expanded and the other colours left quiescent. Thus the animal can assume any particular hue, and change its appearance in a dazzling way with extraordinary rapidity. There is a definite adaptation of the colour assumed in the case of Sepia and others to the colour of the surrounding rock and bottom.

Gonads and Genital Ducts.—In Nautilus it has recently been shown by Lankester and Bourne (37) that the genital ducts of both sexes are paired right and left, the left duct being rudimentary and forming the "pyriform appendage," described by Owen as adhering by membranous attachment to the ventricle of the heart, and shown by Keferstein to communicate by a pore with the exterior. Thus the Cephalopoda agree with our archi-Mollusc in having bilaterally symmetrical genital ducts in the case of the most archaic member of the class. The ovary (female gonad) or the testis (male gonad) lies in Nautilus as in the Dibranchs in a distinct cavity walled off from the other viscera, near the centro-dorsal region. This chamber is formed by the cœlomic or peritoneal wall; the space enclosed is originally part of the cœlom, and in Sepia and Loligo is, in the adult, part of the viscero-pericardial chamber. In Octopus it is this genital chamber which communicates by a right and a left canal with the nephridium, and is the only representative of pericardium. The ovary or testis is itself a growth from the inner wall of this chamber, which it only partly fills. In Nautilus the right genital duct, which is functional, is a simple continuation to the pore on the postero-dorsal surface of the membranous walls of the capsule in which lies the ovary or the testis, as the case may be. The gonad itself appears to represent a single median or bilateral organ.

The true morphological nature of the genital ducts of the Cephalopoda and of other Mollusca is a subject which invites speculation and inquiry. In all the cases in which such

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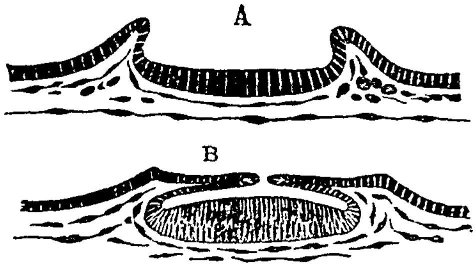

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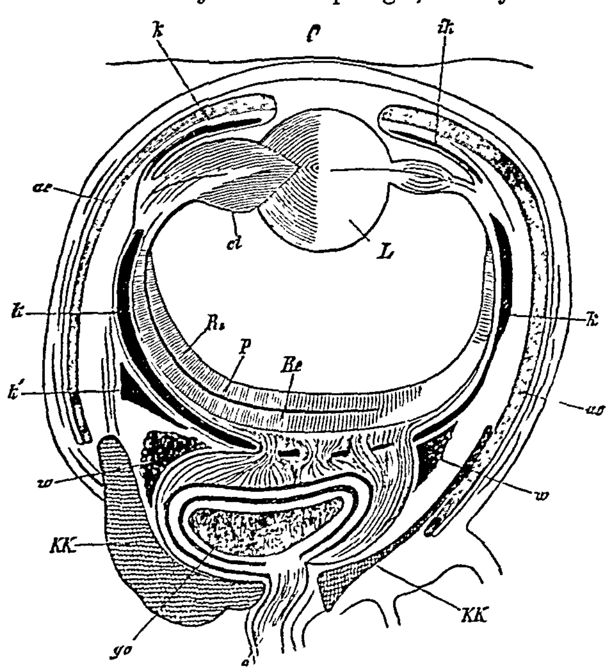

FIG. 120.—Horizontal section of the eye of Sepia (Myopsid). *KK*, cephalic cartilages (see fig. 116); *C*, cornea (closed); *L*, lens; *ci*, ciliary body; *Ri*, internal layer of the retina; *Re*, external layer of the retina; *p*, pigment between these; *o*, optic nerve; *go*, optic ganglion; *k* and *k'*, capsular cartilage; *ik*, cartilage of the iris; *w*, white body; *ae*, argentine integument. (From Gegenbaur, after Hensen.)

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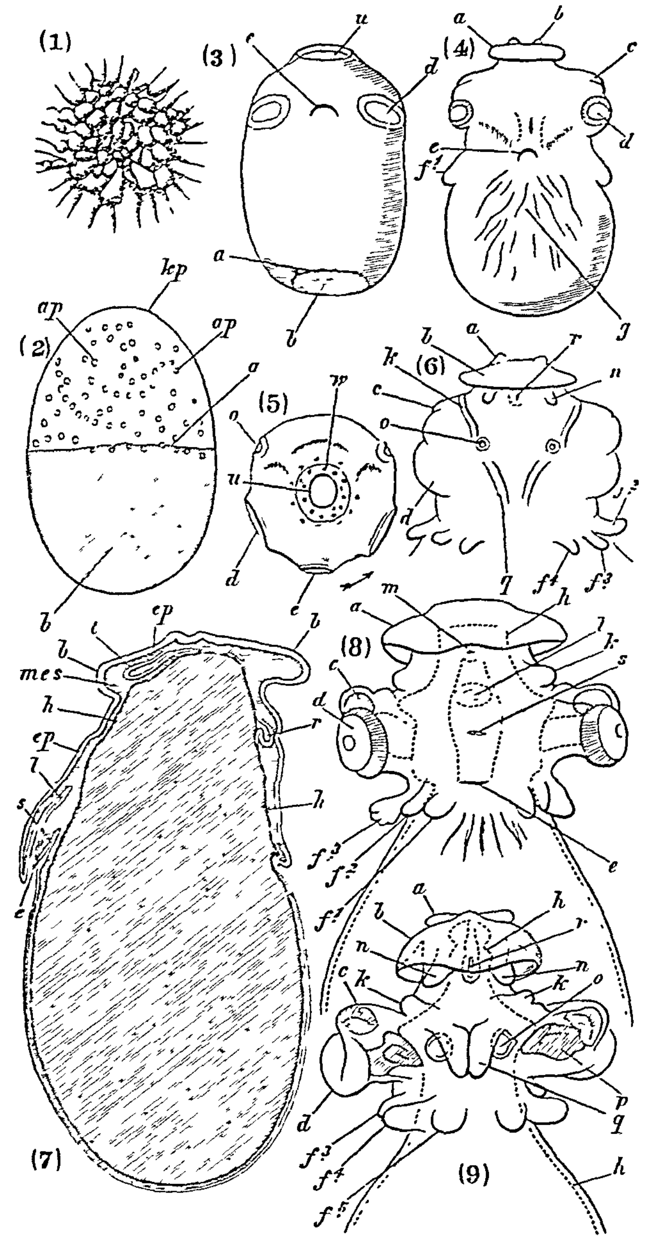

FIG. 121.—Development of Loligo. (1) View of the cleavage of the egg during the first formation of embryonic cells. (2) Lateral view of the egg at a little later stage. *a*, limit to which the layer of cleavage-cells has spread over the egg; *b*, portion of the egg (shaded) as yet uncovered by cleavage-cells; *ap*, the autoplasts; *kp*, cleavage-pole where first cells were formed. (3) Later stage, the limit *a* now extended so as to leave but little of the egg-surface (*b*) unenclosed. The eyes (*d*), mouth (*e*), and mantle-sac (*u*) have appeared. (4) Later stage, anterior surface, the embryo is becoming nipped off from the yelk sac (*g*). (5) View of an embryo similar to (3) from the cleavage-pole or centro-dorsal area. (6) Later stage, posterior surface. (7) Section in a median dorso-ventral and antero-posterior plane of an embryo of the same age as (4). (8) View of the anterior face of an older embryo. (9) View of the posterior face of an embryo of the same age as (8). Letters in (3) to (9):—*a*, lateral fins of the mantle; *b*, mantle-skirt; *c*, supra-ocular invagination to form the "white body"; *d*, the eye; *e*, the mouth; $f^1, ^2, ^3, ^4, ^5$, the five paired processes of the fore-foot; *g*, rhythmically contractile area of the yelk-sac, which is itself a hernia-like protrusion of the median portion of the fore foot (see fig. 72**); *h*, dotted line showing internal area occupied by yelk (food-material of the egg); *k*, first rudiment of the mid-foot (paired ridges which unite to form the siphon or funnel); *l*, sac of the radula or lingual ribbon; *m*, stomach; *n*, rudiments of the gills (paired ctenidia); *o*, the otocysts,—a pair of invaginations of the surface of the mid-foot; *p*, the optic ganglion; *q*, the distal portion of the ridges which form the siphon or mid-foot, *k* being the basal portion of the same structure; *r*, the vesicle-like rudiment of the intestine formed independently of the parts connected with the mouth, *s*, *k*, *m*, and without invagination; *s*, rudiment of the salivary glands; *t* in (7), the shell-sac at an earlier stage open (see fig. 122), now closed up; *u*, the open shell-sac formed by an uprising ring-like growth of the centro-dorsal area; *w* in (5), the mantle skirt commencing to be raised up around the area of the shell-sac. In (7) *mes* points to the middle cell-layer of the embryo, *ep* to the outer layer, and *h* to the deep layer of fusiform cells which separates everywhere the embryo from the yelk or food-material lying within it. (Original.)

but that this is in part to be sought in the widely-separated primitive streak. The present writer has little doubt that a structure corresponding to the primitive streak of the chick, and lying near the klastic pole, will be found in Sepia and Loligo, and the strange vesicular origin of the mid-gut will be traced to and explained by it.

Leaving this difficult question of the cell-layers of the embryo, we would draw the reader's attention to the series of sketches representing the semi-transparent embryo of Loligo, drawn in fig. 121. When the cleavage cells have nearly enclosed the yelk, the upper or embryonic area shows the rudiments of the centro-dorsal mantle-sac or pen-sac, the mouth, the paired optic pits, and the paired

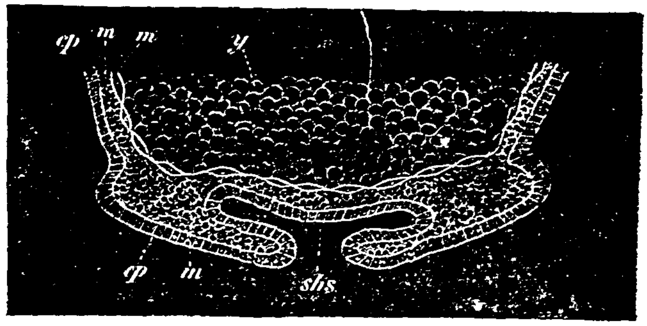

FIG. 122.—Section through the still open shell-sac occupying the centro-dorsal area of an embryo of Loligo; the position is inverted as compared with fig. 121 (3) and (7). *ep*, outer cell-layer; *m*, middle cell-layer; *m'*, deep cell-layer of fusiform cells; *y*, the granular yelk or food-material of the egg; *shs*, the still open shell-sac. (From Lankester.)

otic pits (fig. 121, (3), (5)). The eye-pits close up (fig. 119), the orifice of the mantle-sac narrows, and its margin becomes raised and freely produced as mantle-skirt; at the same time an hour-glass-like pinching in of the whole embryo commences, separating the embryo proper from the so-called yelk-sac (fig. 121, (4)). Around the "waist" of constriction, pair by pair, ten lobes arise (fig. 121, (8)),—the arms of the fore-foot. It now becomes obvious that the yelk-sac is but the median surface of the fore-foot bulged out inordinately by food-yelk, just as the hind region of the foot is in the embryo slug (see fig. 72**, and explanation). Just as in the slug, this dilated yelk-holding foot is rhythmically contractile, and pulsates steadily over the area *g* in fig. 121, (4). At this stage, and long subsequently, the mouth of the young Cephalopod is in no way surrounded by the fore-foot, but lies well above its nascent lobes (*e* in fig. 121). Subsequently it sinks, as it were, between the right and left most anterior pair of the series, which grow towards one another and fuse above it, and leave no trace of their original position and relations. Fig. 121, (6) gives a view of the postero-dorsal surface of an embryo, in which the important fact is seen of the formation of the funnel or siphon by the union of two pieces (*q*), which grow up each independently, one right and one left, like the sides of the siphon of Nautilus or the swimming lobes of a Pteropod, and subsequently come together, as shown in (9), where the same letter *q* indicates the same part. The explanations of figs. 121 and 123 are given very full, and here, therefore, we shall only allude to two additional points. A curious mass of tissue of unknown significance occurs in the orbit of Dibranchs, known as the white body (*w* in fig. 120). A strongly-marked invagination just above the orbit is a very prominent feature in the embryo of Loligo, Sepia, and Octopus, and appears to give rise to this so-called white body. This invaginated portion of the outer cell-layer is seen in fig. 121, (8) and (9), lettered *c*; in fig. 123, A and B, it is lettered *wb*.

Lastly, in fig. 123, A, the origin of the optic nerve-ganglion *ng* from the cells of the middle layer should be especially noticed. In some other Molluscs the nerve-ganglia have been definitely traced to the outer cell-layer,

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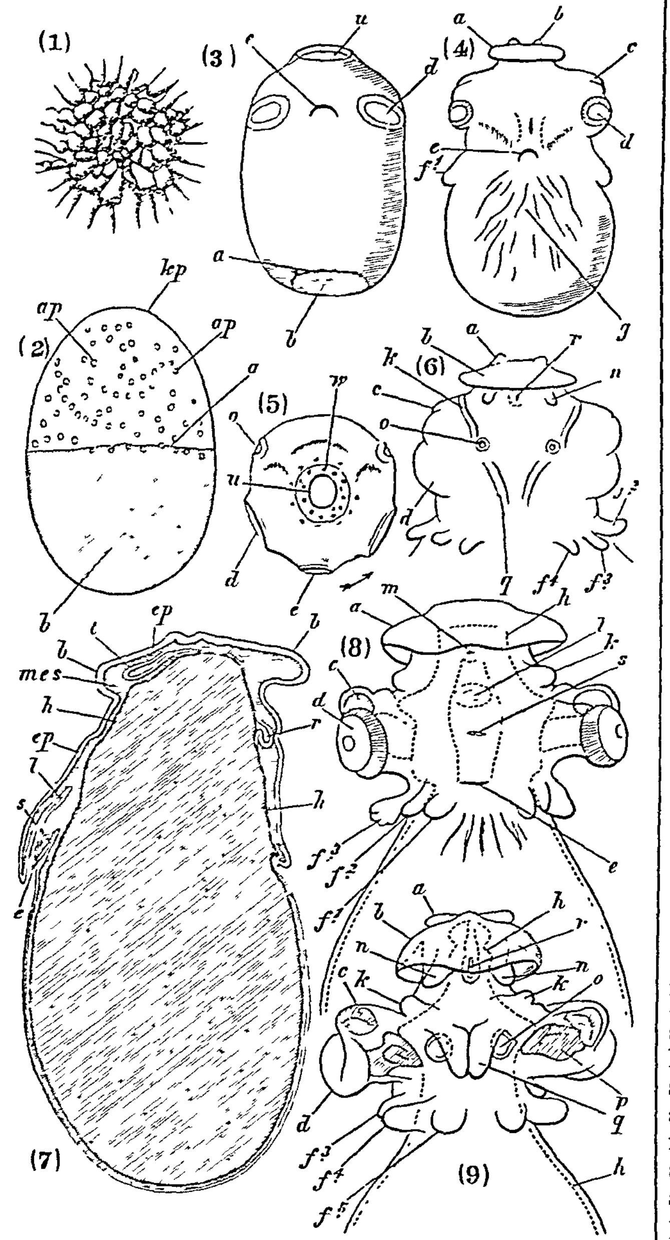

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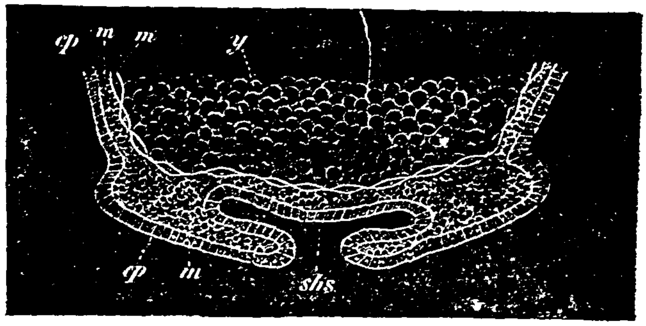

FIG. 122.—Section through the still open shell-sac occupying the centro-dorsal area of an embryo of Loligo; the position is inverted as compared with fig. 121 (3) and (7). *ep*, outer cell-layer; *m*, middle cell-layer; *m'*, deep cell-layer of fusiform cells; *y*, the granular yelk or food-material of the egg; *shs*, the still open shell-sac. (From Lankester.)

otic pits (fig. 121, (3), (5)). The eye-pits close up (fig. 119), the orifice of the mantle-sac narrows, and its margin becomes raised and freely produced as mantle-skirt; at the same time an hour-glass-like pinching in of the whole embryo commences, separating the embryo proper from the so-called yelk-sac (fig. 121, (4)). Around the "waist" of constriction, pair by pair, ten lobes arise (fig. 121, (8)),—the arms of the fore-foot. It now becomes obvious that the yelk-sac is but the median surface of the fore-foot bulged out inordinately by food-yelk, just as the hind region of the foot is in the embryo slug (see fig. 72**, and explanation). Just as in the slug, this dilated yelk-holding foot is rhythmically contractile, and pulsates steadily over the area *g* in fig. 121, (4). At this stage, and long subsequently, the mouth of the young Cephalopod is in no way surrounded by the fore-foot, but lies well above its nascent lobes (*e* in fig. 121). Subsequently it sinks, as it were, between the right and left most anterior pair of the series, which grow towards one another and fuse above it, and leave no trace of their original position and relations. Fig. 121, (6) gives a view of the postero-dorsal surface of an embryo, in which the important fact is seen of the formation of the funnel or siphon by the union of two pieces (*q*), which grow up each independently, one right and one left, like the sides of the siphon of Nautilus or the swimming lobes of a Pteropod, and subsequently come together, as shown in (9), where the same letter *q* indicates the same part. The explanations of figs. 121 and 123 are given very full, and here, therefore, we shall only allude to two additional points. A curious mass of tissue of unknown significance occurs in the orbit of Dibranchs, known as the white body (*w* in fig. 120). A strongly-marked invagination just above the orbit is a very prominent feature in the embryo of Loligo, Sepia, and Octopus, and appears to give rise to this so-called white body. This invaginated portion of the outer cell-layer is seen in fig. 121, (8) and (9), lettered *c*; in fig. 123, A and B, it is lettered *wb*.

Lastly, in fig. 123, A, the origin of the optic nerve-ganglion *ng* from the cells of the middle layer should be especially noticed. In some other Molluscs the nerve-ganglia have been definitely traced to the outer cell-layer,

veloped only in those few forms which are inequivalve. The typical PERICARDIUM is well developed. It appears, as in other Mollusca, not to be a blood-space although developed from the cœlom, and it communicates with the exterior by the pair of nephridia. As in Cephalopoda (and possibly other Mollusca) water can be introduced through the nephridia into this space. The ALIMENTARY CANAL keeps very nearly to the median vertical plane whilst exhibiting a number of flexures and loopings in this plane. A pair of large glandular outgrowths, the so-called "liver" or great digestive gland, exists as in other Molluscs. A pair of pedal OTOCYSTS, and a pair of OSPHRADIA at the base of the gills, appear to be always present. A typical NERVOUS SYSTEM is present (fig. 144), consisting of a cerebro-pleuro-visceral ganglion-pair, united by connectives to a pedal ganglion-pair and an osphradial ganglion-pair (parieto-splanchnic).

A special cæcum connected with the pharynx is sometimes found, containing a tough flexible cylinder of transparent cartilaginous appearance and unknown significance, called the "crystalline style" (Mactra), which possibly represents the radular sac of Glossophora. In many Lamellibranchs a gland is found on the hinder surface of the foot in the mid line, which secretes a substance which sets into the form of threads—the so-called "byssus"—by means of which the animal can fix itself. Sometimes this gland is found in the young and not in the adult (Anodon, Unio, Cyclas). In some Lamellibranchs (Pecten, Spondylus, Pholas, Mactra, Tellina, Pectunculus, Galeomma, &c.), although cephalic eyes are always absent, special eyes are developed on the free margin of the mantle-skirt, apparently by the modification of tentacles which are commonly found there (fig. 145). The existence of pores in the foot and elsewhere in Lamellibranchia by which liquid can pass into and out of the vascular system, although asserted as in the case of other Mollusca, appears to be improbable. It has yet to be shown by satisfactory microscopic sections that the supposed pores are anything but epidermal glands.

The Lamellibranchia live chiefly in the sea, some in fresh waters. A very few have the power of swimming by opening and shutting the valves of the shell (Pecten, Lima); most can slowly crawl or rapidly burrow; others are, when adult, permanently fixed to stones or rocks either by the shell or the byssus. In development some Lamellibranchia pass through a free-swimming trochosphere stage with præoral ciliated band; other fresh-water forms which carry the young in brood-pouches formed by the ctenidia have suppressed this larval phase.

The following classification and enumeration of genera are based primarily upon the characters of the adductor muscles. The Heteromya and Monomya must be conceived of as derived from forms resembling such Gastropodous Isomya as Nucula and Trigonia, which undoubtedly are the nearest living representatives of the ancestral Lipocephala, and bring us nearest to the other branch of the Mollusca, the Glossophora.

Order 1.—Isomya.

Character.—Anterior and posterior adductor muscles of approximately equal size.

Sub-order 1.—*Integripallia.*

Characters.—Marginal attachment of the mantle to the shell not inflected to form a sinus; siphons not developed in some, present in most.

Family 1.—*Arcacea.*
Genera: *Arca*, L. (fig. 132); *Cucullæa*, Lam.; *Pectunculus*, Lam.; *Limopsis*, Sassi; *Nucula*, Lam. (fig. 134); *Isoarca*, Münster; *Leda*, Schu.; *Yoldia*, Möll.; *Solenella*, Sowerby, &c.
Family 2.—*Trigoniacea.*
Genera: *Trigonia*, Brug.; *Axinus*, Sow.; *Lyrodesma*, Conrad.
Family 3.—*Unionacea.*
Genera: *Unio*, Retz.; *Castalia*, Lam.; *Anodon*, Cuv. (figs. 124, &c.); *Iridina*, Lam.; *Mycetopus*, d'Orb., &c.
Family 4.—*Lucinacea.*
Genera: *Lucina*, Brug.; *Corbis*, Cuv.; *Diplodonta*, Brown; *Kellia*, Turton; *Montacuta*, Turton; *Lepton*, Turton; *Galeomma*, Turton; *Astarte*, Sow.; *Crassatella*, Lam.; *Cardinia*, Ag.; *Cardita*, Brug., &c.
Family 5.—*Cyprinacea.*
Genera: *Tridacna*, Da C.; *Chama*, L.; *Dimya*, Ron.; *Diceras*, Lk.; *Isocardia*, Lam.; *Hippopodium*, Sow.; *Cardium*, L.; *Corbicula*, Meg.; *Cyrena*, Lk.; *Cyclas*, Brug. (fig. 146); *Pisidium*, Pfr. (figs. 148-153); *Cyprina*, Lam., &c.

Sub-order 2.—*Sinupallia.*

Characters.—Marginal attachment of the mantle to the shell inflected so as to form a sinus into which the pallial siphons can be withdrawn; siphons always present, and large.

Family 6.—*Veneracea.*
Genera: *Cypricardia*, Lam.; *Tapes*, Megl.; *Cyclina*, Desh.; *Cytherea*, Lam. (figs. 125, &c.); *Chione*, Megl.; *Venus*, L.; *Lucinopsis*, F. H.; *Sanguinolaria*, Lam.; *Psammobia*, Lam. (fig. 130); *Tellina*, L.; *Donax*, L.; *Scrobicularia*, Schu.; *Cumingia*, Sow.; *Rangia*, Dsml.; *Mactra*, L. (fig. 140); *Trigonella*, Da C.; *Vaganella*, Gr.; *Lutraria*, Lam.
Family 7.—*Myacea.*
Genera: *Myochama*, Stb.; *Chamostrea*, Rois; *Pandora*, Sol.; *Thracia*, Leach; *Thetis*, Sow.; *Pholadomya*, Sow.; *Corbula*, Brug.; *Mya*, Lam.; *Saxicava*, Fleur; *Panopæa*, Ad.; *Glycimeris*, Lam.; *Siliqua*, Mhlf., &c.; *Solen*, L.
Family 8.—*Pholadacea.*
Genera: *Clavagella*, Lam.; *Aspergillum*, Lam. (figs. 128, 129); *Humphreyia*, Gr.; *Pholas*, L.; *Pholadidea*, Turt.; *Teredo*, L.; *Teredina*, Lam.; *Furcella*, Oken, &c.

Order 2.—Heteromya.

Characters.—Anterior adductor (pallial adductor) much smaller than the posterior adductor (pedal adductor); siphons rarely present.

Family 1.—*Mytilacea.*
Genera: *Mytilus*, L. (fig. 133); *Modiola*, Lam.; *Crenella*, Brown; *Lithodomus*, Cuv.; *Dreissena*, Ben. (fig. 136); *Modiolarca*, Gr., &c.
Family 2.—*Mulleriacea.*
Genera: *Aetheria*, Lam.; *Mulleria*, Fér.

Order 3.—Monomya.

Characters.—Anterior adductor absent in the adult; siphons never developed.

Family 1.—*Aviculacea.*
Genera: *Cardiola*, Brdp.; *Avicula*, Kl.; *Malleus*, Lam.; *Inoceramus*, Sow.; *Crenatula*, Lam.; *Perna*, Brug., &c.
Family 2.—*Ostracea.*
Genera: *Ostrea*, L. (fig. 6); *Anomia*, L.; *Spondylus*, L.; *Plicatula*, Lam.; *Vulsella*, Lam.; *Lima*, Brug.; *Pecten*, L.; *Hiunites*, Dfr., &c.

Further Remarks on the Lamellibranchia.—The Lamellibranchia are the only members of the Lipocephalous branch of Mollusca existing at the present day; and we must suppose that, whilst on the one hand the earliest Glossophorous forms were developing from the archi-Mollusca by the elaboration of the buccal apparatus, the bivalved sessile Lamellibranchs were developing in another direction from univalve cephalophorous ancestors. The large bilobed mantle-flap with its pair of shells covering in the whole animal, the current-producing largely-expanded ctenidia, and the reduced cephalic region are characters which go hand in hand, and were simultaneously acquired, each being related to the development of the others. Unless the "crystalline style" of Lamellibranchs is to be considered as the rudiment of the "radular sac" of Glossophora, as suggested by Balfour, there is no indication whatever that the ancestors of the Lamellibranchia had acquired a representative of the buccal apparatus—so highly developed in Glossophora—before diverging from the archi-Mollusca; that is to say, the common ancestors of the two great branches of Mollusca presented the distinctive character of neither branch—they had not an aborted cephalic region, and they had not a lingual ribbon.

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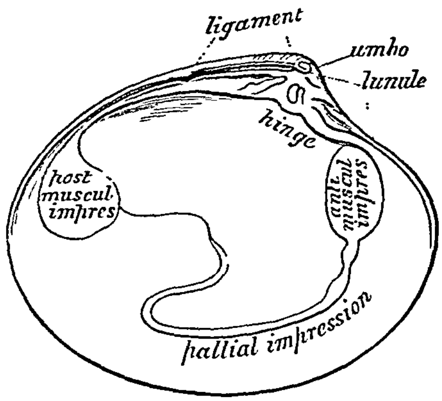

Fig. 127.—Left valve of the same shell from the inner face. (Figs. 125, 126, 127 from Owen.)

In removing the valves of the shell from an Anodon, it is necessary not only to cut through the muscular attachments of the body-wall to the shell but to sever also a *strong elastic ligament, or spring resembling india-rubber*, joining the two shells about the umbonal area. The shell of Anodon does not present these parts in the most strongly marked condition, and accordingly our figures (figs. 125, 126, 127) represent the valves of the Sinupalliate genus Cytherea. The corresponding parts are recognizable in Anodon. Referring to the figures (125, 126) for an explanation of terms applicable to the parts of the valve and the markings on its inner surface—corresponding to the muscular area which we have already noted on the surface of the animal's body—we must specially note here the position of that denticulated thickening of the dorsal margin of the valve which is called the hinge (fig. 127). By this hinge one valve is closely fitted to the other. Below this hinge each shell becomes concave, above it each shell rises a little to form the umbo, and it is into this ridge-like upgrowth of each valve that the elastic ligament or spring is fixed (fig. 127). As shown in the diagram (fig. 127*) representing a transverse section of the two valves of a Lamellibranch, the two shells form a double lever, of which the toothed-hinged is the fulcrum. The adductor muscles placed in the concavity of the shells act upon the long arms of the lever at a mechanical advantage; their contraction keeps the shells shut, and stretches the ligament or spring *h*. On the other hand, the ligament *h* acts upon the short arm formed by the umbonal ridge of the shells; whenever the adductors relax, the elastic substance of the ligament contracts, and the shells gape. It is on this account that the valves of a dead Lamellibranch always gape; the elastic ligament is no longer counteracted by the effort of the adductors. The state of closure of the valves of the shell is not, therefore, one of rest; when it is at rest—that is, when there is no muscular effort—the valves of a Lamellibranch are slightly gaping, and are closed by the action of the adductors when the animal is disturbed. The ligament is simple in Anodon; in many Lamellibranchs it is separated into two layers, an outer and an inner (thicker and denser). That the condition

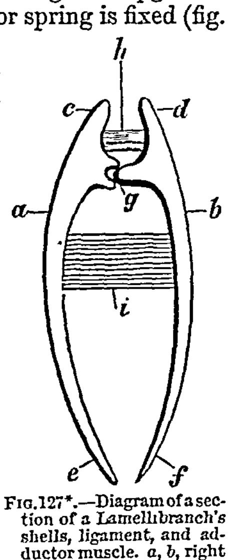

Fig. 127*.—Diagram of a section of a Lamellibranch's shells, ligament, and adductor muscle. *a*, *b*, right and left valves of the shell; *c*, *d*, the umbones or short arms of the lever; *e*, *f*, the long arms of the lever; *g*, the hinge; *h*, the ligament; *i*, the adductor muscle.

of gaping of the shell-valves is essential to the life of the Lamellibranch appears from the fact that food to nourish it, water to aerate its blood, and spermatozoa to fertilize its eggs, are all introduced into this gaping chamber by currents of water, which are set going by the highly-developed ctenidia. The current of water enters into the sub-pallial space at the spot marked *e* in fig. 124, (1), and, after passing as far forward as the mouth *w* in fig. 124, (5), takes an outward course and leaves the sub-pallial space by the upper notch *d*. These notches are known in Anodon as the afferent and efferent siphonal notches respectively, and correspond to the long tube-like afferent inferior and efferent superior "siphons" formed by the mantle in many other Lamellibranchs (fig. 130).

Whilst the valves of the shell are equal in Anodon we find in many Lamellibranchs (Ostræa, Chama, Corbula, &c.) one valve larger, and the other smaller and sometimes flat, whilst the larger shell may be fixed to rock or to stones (Ostræa, &c.). A further variation consists in the development of additional shelly plates upon the dorsal line between the two large valves (Pholadidæ). In *Pholas dactylus* we find a pair of umbonal plates, a dors-umbonal plate and a dorsal plate. It is to be remembered that the whole of the cuticular hard product produced on the dorsal surface and *on the mantle-flaps* is to be regarded as the "shell," of which a median band-like area, the ligament, usually remains uncalcified, so as to result in the production of two valves united by the elastic ligament. But the shelly substance does not always in boring forms adhere to this form after its first growth. In Aspergillum the whole of the tubular mantle area secretes a continuous shelly tube, although in the young condition two valves were present. These are seen (fig. 129) set in the firm substance of the adult tubular shell, which has even replaced the ligament, so that the tube is complete. In Teredo a similar tube is formed as the animal elongates (boring in wood), the original shell-valves not adhering to it but remaining movable and provided with a special muscular apparatus in place of a ligament.

Let us now examine the organs which lie beneath the mantle-skirt of Anodon, and are bathed by the current of water which cir-

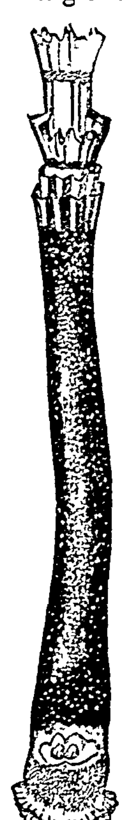

Fig. 128.

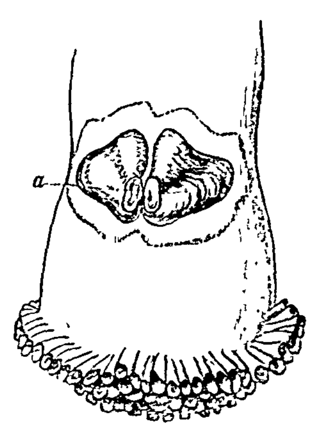

Fig. 129.

Fig. 128.—Shell of *Aspergillum vaginiferum* (from Owen).
Fig. 129.—Shell of *Aspergillum vaginiferum* to show the original valves *a*, now embedded in a continuous calcification of tubular form (from Owen).

culates through it. This can be done by lifting up and throwing back the left half of the mantle-skirt as is represented in fig. 124, (3). We thus expose the plough-like foot (*f*), the two left labial tentacles, and the two left gill-plates or left ctenidium. In fig. 124, (5), one of the labial tentacles *n* is also thrown back so as to show

that the Monomya have been developed from Isomya-like ancestors, and have lost by atrophy their anterior adductor. The single adductor muscle of the Monomya is separated by a difference of fibre into two portions, but neither of these can be regarded as possibly representing the anterior adductor of the other Lamellibranchs. One of these portions is more ligamentous, and serves to keep the two shells constantly attached to one another, whilst the more fleshy portion serves to close the shell rapidly when it has been gaping.

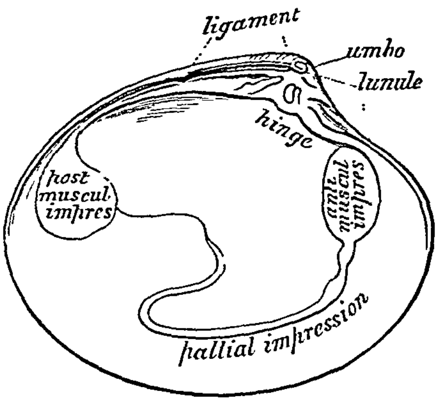

FIG. 127.—Left valve of the same shell from the inner face. (Figs. 125, 126, 127 from Owen.)

In removing the valves of the shell from an Anodon, it is necessary not only to cut through the muscular attachments of the body-wall to the shell but to sever also a strong elastic ligament, or spring resembling india-rubber, joining the two shells about the umbonal area. The shell of Anodon does not present these parts in the most strongly marked condition, and accordingly our figures (figs. 125, 126, 127) represent the valves of the Sinupalliate genus Cytherea. The corresponding parts are recognizable in Anodon. Referring to the figures (125, 126) for an explanation of terms applicable to the parts of the valve and the markings on its inner surface—corresponding to the muscular area which we have already noted on the surface of the animal's body—we must specially note here the position of that denticulated thickening of the dorsal margin of the valve which is called the hinge (fig. 127). By this hinge one valve is closely fitted to the other. Below this hinge each shell becomes concave, *above it each shell rises a* little to form the umbo, and it is into this ridge-like upgrowth of each valve that the elastic ligament or spring is fixed (fig. 127). As shown in the diagram (fig. 127*) representing a transverse section of the two valves of a Lamellibranch, the two shells form a double lever, of which the toothed-hinged is the fulcrum. The adductor muscles placed in the concavity of the shells act upon the long arms of the lever at a mechanical advantage; their contraction keeps the shells shut, and stretches the ligament or spring *h*. On the other hand, the ligament *h* acts upon the short arm formed by the umbonal ridge of the shells; whenever the adductors relax, the elastic substance of the ligament contracts, and the shells gape. It is on this account that the valves of a dead Lamellibranch always gape; the elastic ligament is no longer counteracted by the effort of the adductors. The state of closure of the valves of the shell is not, therefore, one of rest; when it is at rest—that is, when there is no muscular effort—the valves of a Lamellibranch are slightly gaping, and are closed by the action of the adductors when the animal is disturbed. The ligament is simple in Anodon; in many Lamellibranchs it is separated into two layers, an outer and an inner (thicker and denser). That the condition

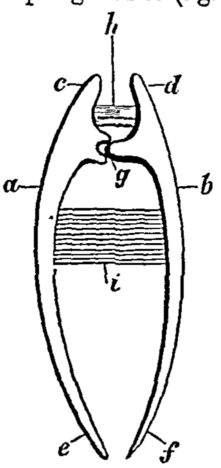

FIG. 127*.—Diagram of a section of a Lamellibranch's shells, ligament, and adductor muscle. *a*, *b*, right and left valves of the shell; *c*, *d*, the umbones or short arms of the lever; *e*, *f*, the long arms of the lever; *g*, the hinge; *h*, the ligament; *i*, the adductor muscle.

of gaping of the shell-valves is essential to the life of the Lamellibranch appears from the fact that food to nourish it, water to aerate its blood, and spermatozoa to fertilize its eggs, are all introduced into this gaping chamber by currents of water, which are set going by the highly-developed ctenidia. The current of water enters into the sub-pallial space at the spot marked *e* in fig. 124, (1), and, after passing as far forward as the mouth *w* in fig. 124, (5), takes an outward course and leaves the sub-pallial space by the upper notch *d*. These notches are known in Anodon as the afferent and efferent siphonal notches respectively, and correspond to the long tube-like afferent inferior and efferent superior "siphons" formed by the mantle in many other Lamellibranchs (fig. 130).

Whilst the valves of the shell are equal in Anodon we find in many Lamellibranchs (Ostræa, Chama, Corbula, &c.) one valve larger, and the other smaller and sometimes flat, whilst the larger shell may be fixed to rock or to stones (Ostræa, &c.). A further variation consists in the development of additional shelly plates upon the dorsal line between the two large valves (Pholadidæ). In *Pholas dactylus* we find a pair of umbonal plates, a dors-umbonal plate and a dorsal plate. It is to be remembered that the whole of the cuticular hard product produced on the dorsal surface and on the mantle-flaps is to be regarded as the "shell," of which a median band-like area, the ligament, usually remains uncalcified, so as to result in the production of two valves united by the elastic ligament. But the shelly substance does not always in boring forms adhere to this form after its first growth. In Aspergillum the whole of the tubular mantle area secretes a continuous shelly tube, although in the young condition two valves were present. These are seen (fig. 129) set in the firm substance of the adult tubular shell, which has even replaced the ligament, so that the tube is complete. In Teredo a similar tube is formed as the animal elongates (boring in wood), the original shell-valves *not adhering to it but remaining movable* and provided with a special muscular apparatus in place of a ligament.

Let us now examine the organs which lie beneath the mantle-skirt of Anodon, and are bathed by the current of water which circulates through it. This can be done by lifting up and throwing back the left half of the mantle-skirt as is represented in fig. 124, (3). We thus expose the plough-like foot (*f*), the two left labial tentacles, and the two left gill-plates or left ctenidium. In fig. 124, (5), one of the labial tentacles *n* is also thrown back so as to show

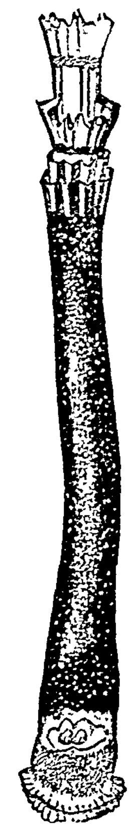

Fig. 128.

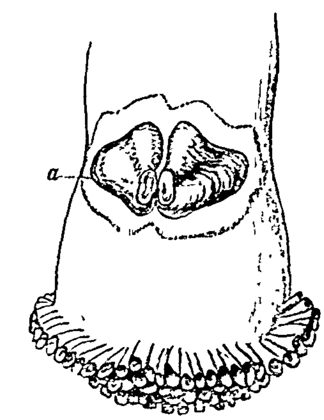

Fig. 129.

FIG. 128.—Shell of *Aspergillum vaginiferum* (from Owen).
FIG. 129.—Shell of *Aspergillum vaginiferum* to show the original valves *a*, now embedded in a continuous calcification of tubular form (from Owen).

doubled on themselves in fact—and thus form an additional row of filaments (see fig. 133, B). Consequently, each primitive filament has a descending and an ascending ramus, and instead of each row forming a simple plate, the plate is double, consisting of a descending and an ascending lamella. As the axis of the ctenidium lies by the side of the body, and is very frequently connate with the body, as so often happens in Gastropods also, we find it convenient to speak of the two plate-like structures formed on each ctenidial axis as the outer and the inner gill-plate; each of these is

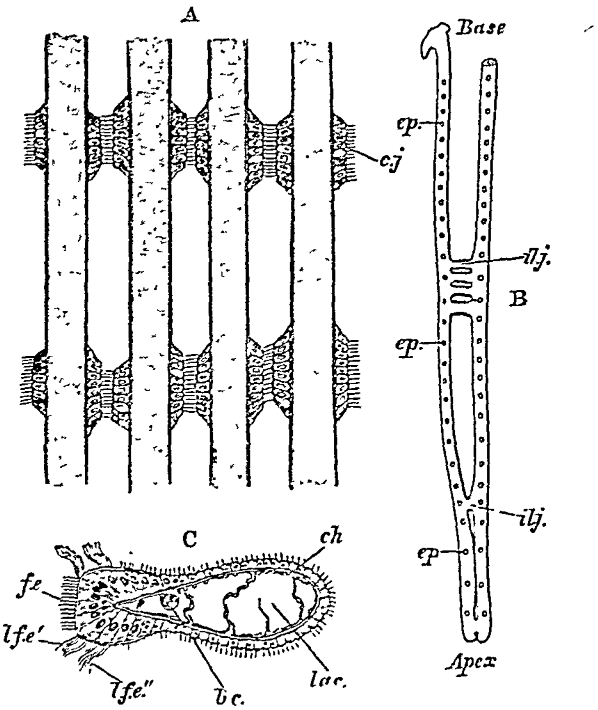

Fig. 133.—Filaments of the ctenidium of *Mytilus edulis* (after Holman Peck). A. Part of four filaments seen from the outer face in order to show the ciliated junctions *c.j.* B. Diagram of the posterior face of a single complete filament with descending ramus and ascending ramus ending in a hook like process. *ep.*, *ep.*, the ciliated junctions; *il.j.*, inter-lamellar junction. C. Transverse section of a filament taken so as to cut neither a ciliated junction nor an inter-lamellar junction. *f.e.*, frontal epithelium; *l.f.e'.*, *l.f.e''.*, the two rows of latero-frontal epithelial cells with long cilia; *ch*, chitonous tubular lining of the filament; *lac.*, blood lacuna traversed by a few processes of connective tissue cells; *b.c.*, blood-corpuscle.

composed of two lamellæ, an outer (the reflected) and an adaxial in the case of the outer gill-plate, and an adaxial and an inner (the reflected) in the case of the inner gill-plate. This is the condition seen in Arca and Mytilus, the so-called plates dividing upon the slightest touch into their constituent filaments, which are but loosely conjoined by their "ciliated junctions." Complications follow upon this in other forms. Even in Mytilus and Arca a connexion is here and there formed between the ascending and descending rami of a filament by hollow extensible outgrowths called "interlamellar junctions" (*il.j* in B, fig. 133). Nevertheless the filament is a complete tube formed of chitonous substance and clothed externally by ciliated epithelium, internally by endothelium and lacunar tissue—a form of connective tissue—as shown in fig. 133, C. Now let us suppose, as happens in the genus Dreissena—a genus not far removed from Mytilus—that the ciliated inter-filamentar junctions (fig. 136) give place to solid permanent inter-filamentar junctions, so that the filaments are converted, as it were, into a trellis-work. Then let us suppose that the inter-lamellar junctions which we have already noted in Mytilus become very numerous, large, and irregular; by them the two trellis-works of filaments would be united so as to leave only a sponge-like set of spaces between them. Within the trabeculæ of the sponge-work blood circulates, and between the trabeculæ the water passes, having entered by the apertures left in the trellis-work formed by the united gill-filaments (fig. 138, A, B). The larger the intra-lamellar spongy

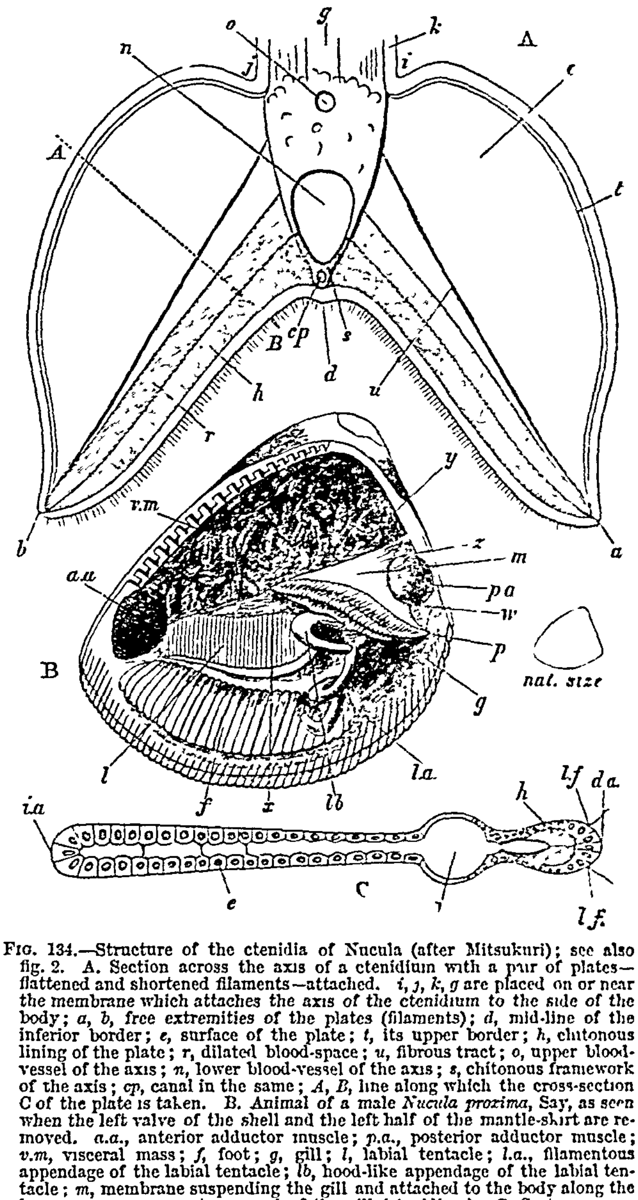

Fig. 134.—Structure of the ctenidia of Nucula (after Mitsukuri); see also fig. 2. A. Section across the axis of a ctenidium with a pair of plates—flattened and shortened filaments—attached. *i*, *j*, *k*, *g* are placed on or near the membrane which attaches the axis of the ctenidium to the side of the body; *a*, *b*, free extremities of the plates (filaments); *d*, mid-line of the inferior border; *e*, surface of the plate; *t*, its upper border; *h*, chitonous lining of the plate; *r*, dilated blood-space; *u*, fibrous tract; *o*, upper blood-vessel of the axis; *n*, lower blood-vessel of the axis; *s*, chitonous framework of the axis; *cp*, canal in the same; *A*, *B*, line along which the cross-section C of the plate is taken. B. Animal of a male *Nucula proxima*, Say, as seen when the left valve of the shell and the left half of the mantle-skirt are removed. *a.a.*, anterior adductor muscle; *p.a.*, posterior adductor muscle; *v.m*, visceral mass; *f*, foot; *g*, gill; *l*, labial tentacle; *l.a.*, filamentous appendage of the labial tentacle; *lb*, hood-like appendage of the labial tentacle; *m*, membrane suspending the gill and attached to the body along the line *x*, *y*, *z*, *w*; *p*, posterior end of the gill (ctenidium). C. Section across one of the gill-plates (*A*, *B*, in A) comparable with fig. 133, C. *i.a.*, border; *d.a.*, axial border; *l.f.*, latero-frontal epithelium; *e*, epithelium of general surface; *r*, dilated blood-space; *h*, chitonous lining (compare A).

growth becomes, the more do the original gill-filaments lose the character of blood-holding tubes and tend to become dense elastic rods for the simple purpose of supporting the spongy growth. This is seen both in the section of Dreissena gill (fig. 136) and in those of Anodon (fig. 137, A, B, C). In the drawing of Dreissena the individual filaments *f*, *f*, *f* are cut across in one lamella at the horizon of an inter-filamentar junction, in the other (lower in the figure) at a point where they are free. The chitonous substance *ch* is observed to be greatly thickened as compared with what it is in fig. 133, C, tending in fact to obliterate altogether the lumen of the filament. And in Anodon (fig. 137, C) this obliteration is effected. In Anodon, besides being thickened, the skeletal substance of the filament develops a specially dense rod-like body on each side of each filament. Although the structure of the ctenidium is thus highly complicated in Anodon, it is yet more so in some of the Siphonate genera of Lamellibranchs. The filaments take on a secondary grouping, the surface of the lamella being thrown into a series of half-cylindrical ridges, each consisting of ten or twenty filaments; a filament

doubled on themselves in fact—and thus form an additional row of filaments (see fig. 133, B). Consequently, each primitive filament has a descending and an ascending ramus, and instead of each row forming a simple plate, the plate is double, consisting of a descending and an ascending lamella. As the axis of the ctenidium lies by the side of the body, and is very frequently connate with the body, as so often happens in Gastropods also, we find it convenient to speak of the two plate-like structures formed on each ctenidial axis as the outer and the inner gill-plate; each of these is

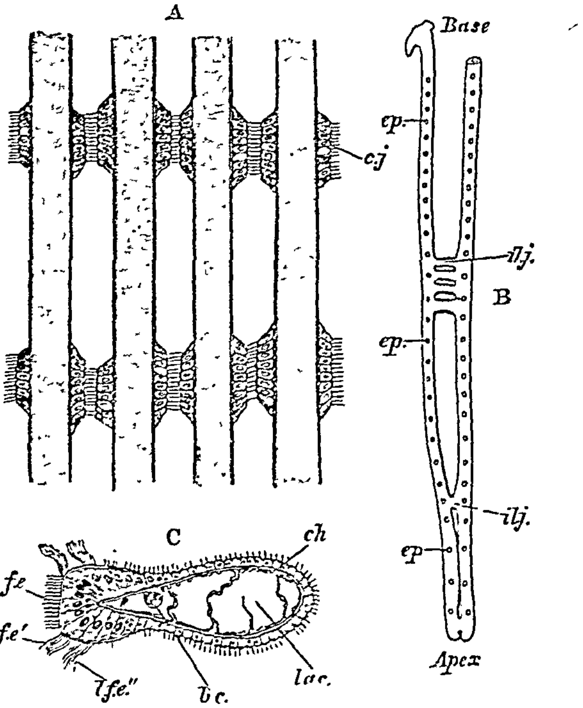

Fig. 133.—Filaments of the ctenidium of *Mytilus edulis* (after Holman Peck). A. Part of four filaments seen from the outer face in order to show the ciliated junctions *c.j.* B. Diagram of the posterior face of a single complete filament with descending ramus and ascending ramus ending in a hook like process. *ep.*, *ep.*, the ciliated junctions; *il.j.*, inter-lamellar junction. C. Transverse section of a filament taken so as to cut neither a ciliated junction nor an inter-lamellar junction. *f.e.*, frontal epithelium; *l.f.e'.*, *l.f.e''.*, the two rows of latero-frontal epithelial cells with long cilia; *ch*, chitonous tubular lining of the filament; *lac.*, blood lacuna traversed by a few processes of connective tissue cells; *b.c.*, blood-corpuscle.

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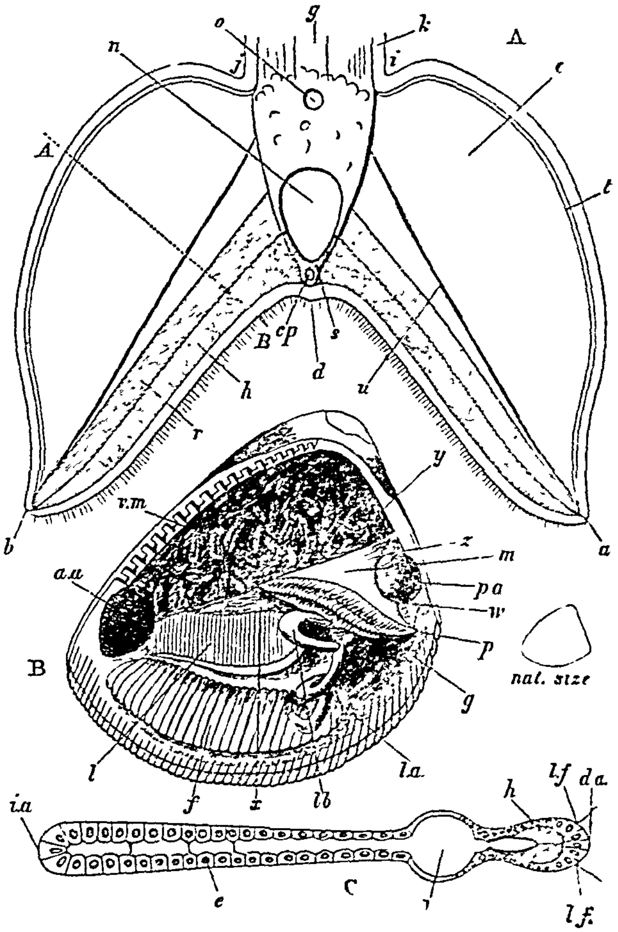

Fig. 134.—Structure of the ctenidia of Nucula (after Mitsukuri); see also fig. 2. A. Section across the axis of a ctenidium with a pair of plates—flattened and shortened filaments—attached. *i*, *j*, *k*, *g* are placed on or near the membrane which attaches the axis of the ctenidium to the side of the body; *a*, *b*, free extremities of the plates (filaments); *d*, mid-line of the inferior border; *e*, surface of the plate; *t*, its upper border; *h*, chitonous lining of the plate; *r*, dilated blood-space; *u*, fibrous tract; *o*, upper blood-vessel of the axis; *n*, lower blood-vessel of the axis; *s*, chitonous framework of the axis; *cp*, canal in the same; *A*, *B*, line along which the cross-section C of the plate is taken. B. Animal of a male *Nucula proxima*, Say, as seen when the left valve of the shell and the left half of the mantle-skirt are removed. *a.a.*, anterior adductor muscle; *p.a.*, posterior adductor muscle; *v.m*, visceral mass; *f*, foot; *g*, gill; *l*, labial tentacle; *l.a.*, filamentous appendage of the labial tentacle; *lb*, hood-like appendage of the labial tentacle; *m*, membrane suspending the gill and attached to the body along the line *x*, *y*, *z*, *w*; *p*, posterior end of the gill (ctenidium). C. Section across one of the gill-plates (*A*, *B*, in A) comparable with fig. 133, C. *i.a.*, border; *d.a.*, axial border; *l.f.*, latero-frontal epithelium; *e*, epithelium of general surface; *r*, dilated blood-space; *h*, chitonous lining (compare A).

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get the arrangement shown diagrammatically in fig. 135, C, and more correctly in fig. 142. In this region the inner lamellæ of the inner gill-plates are no longer affixed to the foot. Passing still further back behind the foot, we find

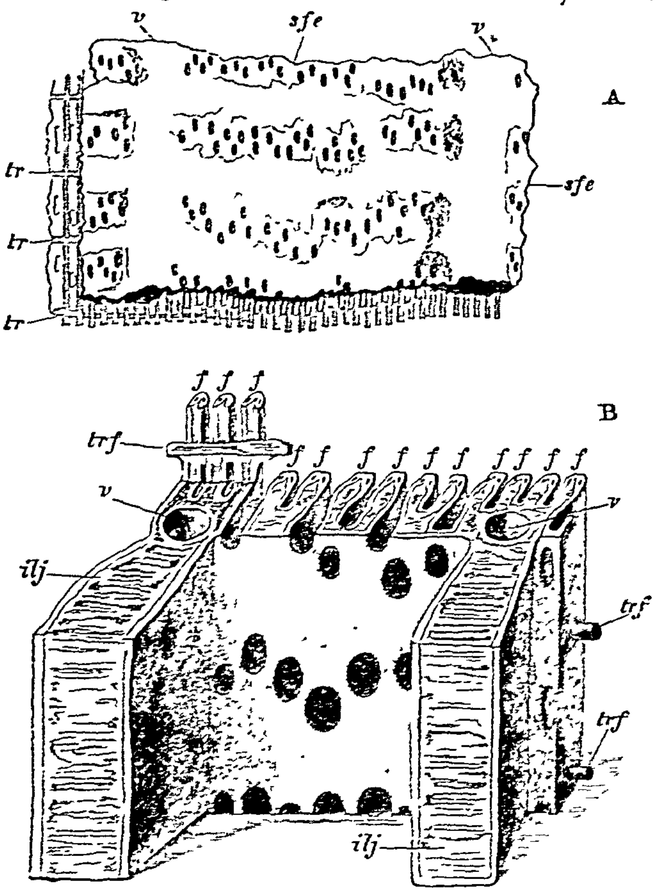

FIG. 138.—Gill-lamellæ of Anodon (after Peck). A. Fragment of the outer lamella of an inner gill-plate torn from the connected inner lamella, the sub-filamentar tissue also partly cut away round the edges so as to expose the filaments, their transverse junctions *tr*, and the "windows" left in the lattice-work; *sfe*, internal surface of the lamella; *v*, vessel. B. Diagram of a block cut from the outer lamella of the outer gill-plate and seen from the inter-lamellar surface (after Peck). *f*, constituent filaments; *trf*, fibrous tissue of the transverse inter-filamentar junctions; *v*, blood-vessel; *ilj*, inter-lamellar junction. The series of oval holes on the back of the lamella are the water-pores which open between the filaments in irregular rows separated horizontally by the transverse inter-filamentar junctions.

in Anodon the condition shown in the section D, fig. 135. The axes *i* are now free; the outer lamellæ of the outer gill-plates (*er*) still adhere by concrescence to the mantle-skirt, whilst the inner lamellæ of the inner gill-plates meet one another and fuse by concrescence at *g*. In the lateral view of the animal with reflected mantle-skirt and gill-plates, the line of concrescence of the inner lamellæ of the inner gill-plates is readily

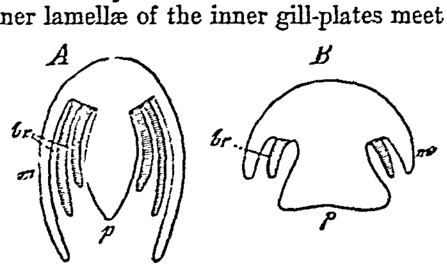

FIG. 139.—Transverse sections of *A*, a Lamellibranch, and *B*, an Isopleurous Gastropod (Chiton), to show the relations of *p*, the foot; *br*, the branchiæ; and *m*, the mantle. (From Gegenbaur.)

seen; it is marked *aa* in fig. 124, (5). In the same figure the free part of the inner lamella of the inner gill-plate resting on the foot is marked *z*, whilst the attached part—the most anterior—has been snipped with scissors so as to show the genital and nephridial apertures *x* and *y*. The concrescence, then, of the free edge of the reflected lamellæ of the gill-plates of Anodon is very extensive. It is important, because such a concrescence is by no means universal, and does not occur, for example, in Mytilus or in Arca; further, because when its occurrence is once appreciated, the reduction of the gill-plates of Anodon to the plume-type of the simplest ctenidium presents no difficulty; and, lastly, it has importance in reference to its physiological significance. The mechanical result of the concrescence of the outer lamellæ to the mantle-flap, and of the inner lamellæ to one another as shown in section D, fig. 135, is that the sub-pallial space is divided into two spaces by a horizontal septum. The upper space (*i*) communicates with the outer world by the excurrent or superior siphonal notch of the mantle (fig. 124, *d*); the lower space communicates by the lower siphonal notch (*e* in fig. 124). The only communication between the two spaces, excepting through the trellis-work of the gill-plates, is by the slit (*z* in fig. 124, (5)) left by the non-concrescence of a part of the inner lamella of the inner gill-plate with the foot. A probe (*g*) is introduced through this slit-like passage, and it is seen to pass out by the excurrent siphonal notch. It is through this passage, or indirectly through the pores of the gill-plates, that the water introduced into the lower sub-pallial space must pass on its way to the excurrent siphonal notch. Such a subdivision of the pallial chamber, and direction of the

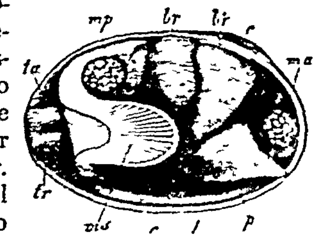

FIG. 140.—Lateral view of a Mactra, the right valve of the shell and right mantle-flap removed, and the siphons retracted. *br*, *br'*, outer and inner gill-plates; *t*, labial tentacle; *ta*, *tr*, upper and lower siphons; *ms*, siphonal muscle of the mantle flap; *ma*, anterior adductor muscle; *mp*, posterior adductor muscle; *p*, foot; *c*, umbo. (From Gegenbaur.)

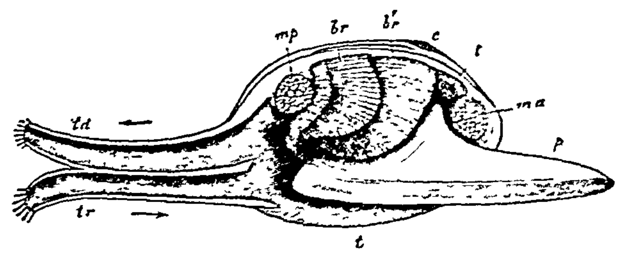

FIG. 141.—The same animal as fig. 140, with its foot and siphons expanded. Letters as in fig. 140. (From Gegenbaur.)

currents set up within it do not exist in a number of Lamellibranchs which have the gill-lamellæ comparatively free (Mytilus, Arca, Trigonia, &c.), and it is in these f[illegible] that there is least modification by concrescence of the pri[illegible] mary filamentous elements of the lamellæ. Probably th[illegible] gill-structure of Lamellibranchs will ultimately fu[illegible] some classificatory characters of value when they ha[illegible] been thoroughly investigated throughout the class.

The alimentary canal of Anodon is shown in fig. 124, (4[illegible] The mouth is placed between the anterior adductor an[illegible] the foot; the anus opens on a median papilla overlyin[illegible] the posterior adductor, and discharges into the superio[illegible] pallial chamber along which the excurrent stream passes The coil of the intestine in Anodon is similar to that [illegible] other Lamellibranchs, but the crystalline style and [illegible] diverticulum are not present here. The rectum traver[illegible] the pericardium, and has the ventricle of the heart wrap[illegible] as it were, around it. This is not an unusual arrangeme[illegible] in Lamellibranchs, and a similar disposition occurs in [illegible] Gastropoda (Haliotis). A pair of ducts (*ai*) lead from t[illegible] first enlargement of the alimentary tract called stoma[illegible] into a pair of large digestive glands, the so-called li[illegible] the branches of which are closely packed in this regi[illegible] (*af*). The food of the Anodon, as of other Lamellibranch[illegible] consists of microscopic animal and vegetable organism[illegible] which are brought to the mouth by the stream which se[illegible] into the sub-pallial chamber at the lower siphonal not[illegible] (*e* in fig. 124). Probably a straining of water from sol[illegible]

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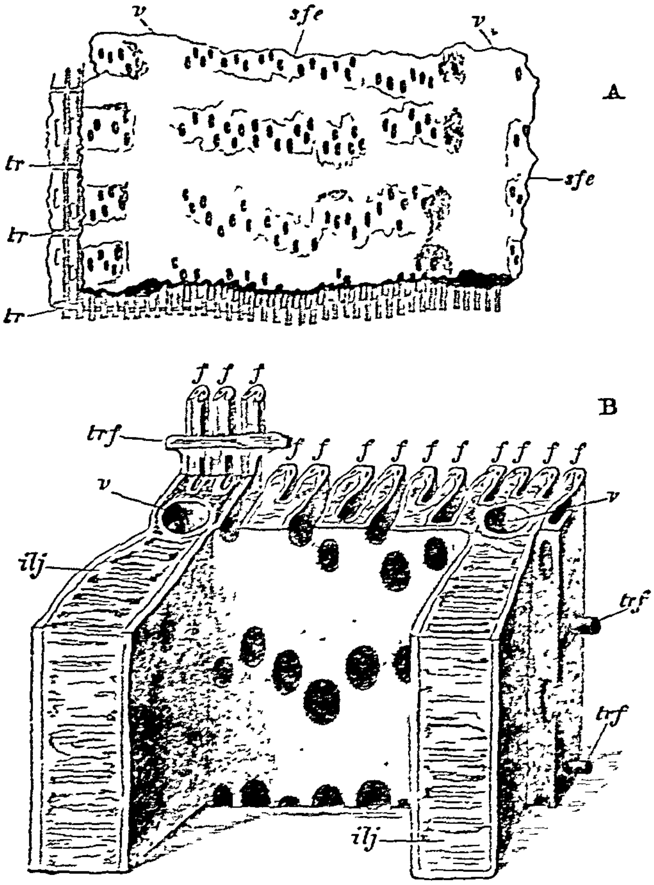

FIG. 138.—Gill-lamellæ of Anodon (after Peck). A. Fragment of the outer lamella of an inner gill-plate torn from the connected inner lamella, the sub-filamentar tissue also partly cut away round the edges so as to expose the filaments, their transverse junctions *tr*, and the "windows" left in the lattice-work; *sfe*, internal surface of the lamella; *v*, vessel. B. Diagram of a block cut from the outer lamella of the outer gill-plate and seen from the inter-lamellar surface (after Peck). *f*, constituent filaments; *trf*, fibrous tissue of the transverse inter-filamentar junctions; *v*, blood-vessel; *ilj*, inter-lamellar junction. The series of oval holes on the back of the lamella are the water-pores which open between the filaments in irregular rows separated horizontally by the transverse inter-filamentar junctions.

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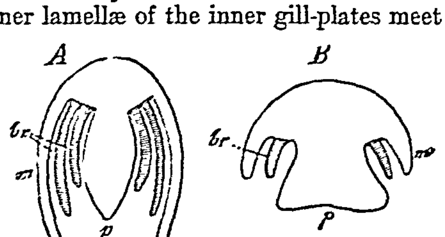

FIG. 139.—Transverse sections of *A*, a Lamellibranch, and *B*, an Isopleurous Gastropod (Chiton), to show the relations of *p*, the foot; *br*, the branchiæ; and *m*, the mantle. (From Gegenbaur.)

seen; it is marked *aa* in fig. 124, (5). In the same figure the free part of the inner lamella of the inner gill-plate resting on the foot is marked *z*, whilst the attached part—the most anterior—has been snipped with scissors so as to show the genital and nephridial apertures *x* and *y*. The concrescence, then, of the free edge of the reflected lamellæ of the gill-plates of Anodon is very extensive. It is important, because such a concrescence is by no means universal, and does not occur, for example, in Mytilus or in Arca; further, because when its occurrence is once appreciated, the reduction of the gill-plates of Anodon to the plume-type of the simplest ctenidium presents no difficulty; and, lastly, it has importance in reference to its physiological significance. The mechanical result of the concrescence of the outer lamellæ to the mantle-flap, and of the inner lamellæ to one another as shown in section D, fig. 135, is that the sub-pallial space is divided into two spaces by a horizontal septum. The upper space (*t*) communicates with the outer world by the excurrent or superior siphonal notch of the mantle (fig. 124, *d*); the lower space communicates by the lower siphonal notch (*e* in fig. 124). The only communication between the two spaces, excepting through the trellis-work of the gill-plates, is by the slit (*z* in fig. 124, (5)) left by the non-concrescence of a part of the inner lamella of the inner gill-plate with the foot. A probe (*g*) is introduced through this slit-like passage, and it is seen to pass out by the excurrent siphonal notch. It is through this passage, or indirectly through the pores of the gill-plates, that the water introduced into the lower sub-pallial space must pass on its way to the excurrent siphonal notch. Such a subdivision of the pallial chamber, and direction of the

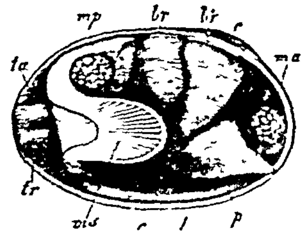

FIG. 140.—Lateral view of a Mactra, the right valve of the shell and right mantle-flap removed, and the siphons retracted. *br*, *br'*, outer and inner gill-plates; *t*, labial tentacle; *ta*, *tr*, upper and lower siphons; *mr*, siphonal muscle of the mantle flap; *ma*, anterior adductor muscle; *mp*, posterior adductor muscle; *p*, foot; *c*, umbo. (From Gegenbaur.)

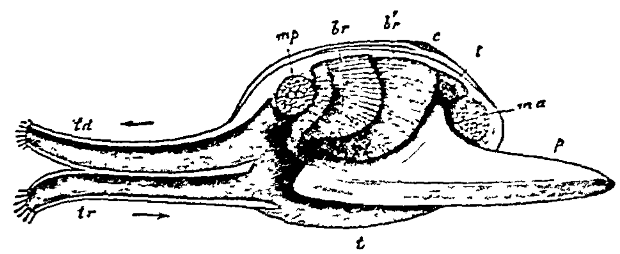

FIG. 141.—The same animal as fig. 140, with its foot and siphons expanded. Letters as in fig. 140. (From Gegenbaur.)

currents set up within it do not exist in a number of Lamellibranchs which have the gill-lamellæ comparatively free (Mytilus, Arca, Trigonia, &c.), and it is in these f[illegible] that there is least modification by concrescence of the pri mary filamentous elements of the lamellæ. Probably th gill-structure of Lamellibranchs will ultimately fu[illegible] some classificatory characters of value when they ha been thoroughly investigated throughout the class.

The alimentary canal of Anodon is shown in fig. 124, (4) The mouth is placed between the anterior adductor an the foot; the anus opens on a median papilla overlyin the posterior adductor, and discharges into the superio pallial chamber along which the excurrent stream passes The coil of the intestine in Anodon is similar to that [illegible] other Lamellibranchs, but the crystalline style and diverticulum are not present here. The rectum traver[illegible] the pericardium, and has the ventricle of the heart wrap[illegible] as it were, around it. This is not an unusual arrangeme in Lamellibranchs, and a similar disposition occurs in [illegible] Gastropoda (Haliotis). A pair of ducts (*ai*) lead from th first enlargement of the alimentary tract called stomac into a pair of large digestive glands, the so-called li[illegible] the branches of which are closely packed in this regic (*af*). The food of the Anodon, as of other Lamellibranch consists of microscopic animal and vegetable organism which are brought to the mouth by the stream which se into the sub-pallial chamber at the lower siphonal notc (*e* in fig. 124). Probably a straining of water from soli

mouth (fig. 144, B, *a*) and connected in front of it by a commissure, are the representatives of the cerebral, pleural, and visceral ganglia of the typical Mollusc, which are not here differentiated as they are in Gastropods (compare, however, fig. 67). A pair placed close together in the foot (fig. 144, B, *b*, and fig. 124, (6), *ax*) are the typical *pedal ganglia; they* are joined to the cerebro-pleuro-visceral ganglia by connectives.

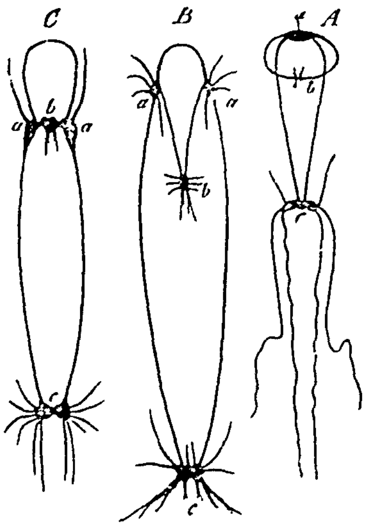

FIG 144.—Nerve ganglia and cords of three Lamellibranchs (from Gegenbaur): *A*, of Teredo; *B*, of Anodonta; *C*, of Pecten. *a*, cerebral ganglion pair (=cerebro pleuro visceral); *b*, pedal ganglion-pair; *c*, olfactory (osphradial) ganglion pair.

Posteriorly beneath the posterior adductors, and covered only by a thin layer of elongated epidermal cells, are the olfactory ganglia, their epidermal clothing constituting the pair of osphradia, which are thus seen in Lamellibranchs to occupy their typical position and to have the typical innervation,—the nerve to each osphradium being given off by the visceral ganglion—that is to say, by the undifferentiated cerebro-pleuro-visceral ganglion of its proper side. This identification of the posterior ganglion-pair of Lamellibranchs is due to Spengel (11). Other

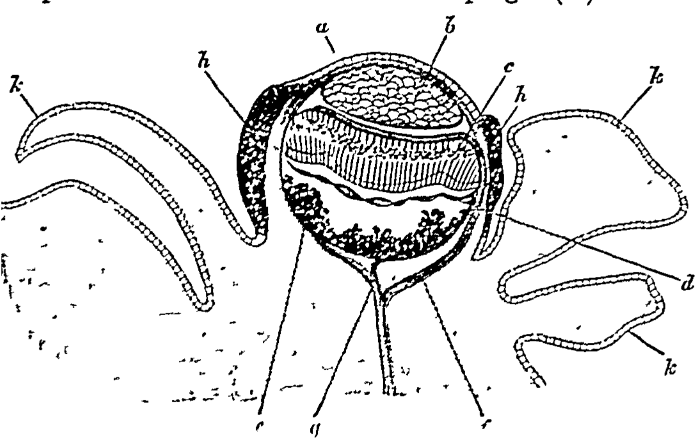

FIG 145.—Pallial eye of Spondylus (from Hickson) *a*, præ-corneal epithelium; *b*, cellular lens; *c*, retinal body; *d*, tapetum; *e*, pigment; *f*, retinal nerve; *g*, complementary nerve; *h*, epithelial cells filled with pigment; *k*, tentacle

anatomists have considered this ganglion-pair as corresponding to either the pleural or the visceral of Gastropoda, or to both, and very usually it is termed "the parieto-splanchnic" (Huxley).

The sense-organs of Anodon other than the osphradia consist of a pair of otocysts attached to the pedal ganglia (fig. 124, (6), *ay*). The otocysts of Cyclas are peculiarly favourable for study on account of the transparency of the small foot in which they lie, and may be taken as typical of those of Lamellibranchs generally. The structure of one is exhibited in fig. 146. A single otolith is present as in the veliger embryos of Opisthobranchia. In adult Gastropoda there are frequently a large number of rod-like otoliths instead of one.

Anodon has no eyes of any sort, and the tentacles on the mantle edge are limited to its posterior border. This deficiency is very usual in the class; at the same time, many Lamellibranchs have tentacles on the edge of the mantle supplied by a pair of large well-developed nerves, which are given off from the cerebro-pleuro-visceral ganglion-pair, and very frequently some of these tentacles have undergone a special metamorphosis converting them into highly-organized eyes. Such eyes on the mantle-edge are found in Pecten, Spondylus, Lima, Ostrea (?), Pinna, Pectunculus, Modiola, Mytilus (?), Cardium, Tellina, Mactra, Venus, Solen, Pholas, and Galeomma. They are totally distinct from the cephalic eyes of typical Mollusca, and have a different structure and historical development. They have not originated as pits but as tentacles. They agree with the dorsal eyes of Onchidium (Pulmonata) in the curious fact that the optic nerve penetrates the capsule of the eye and passes in front of the retinal body (fig. 145), so that its fibres join the anterior faces of the nerve-end cells as in Vertebrates, instead of their posterior faces as in the cephalic eyes of Mollusca and Arthropoda; moreover, the lens is not a cuticular product but a cellular structure, which, again, is a feature of agreement with the Vertebrate eye. It must, however, be distinctly borne in mind that there is a fundamental difference between the eye of Vertebrates and of all other groups in the fact that in the Vertebrata the retinal body is itself a part of the central nervous system, and not a separate modification of the epidermis—myelonic as opposed to epidermic. The structure of the reputed eyes of several of the above-named genera has not been carefully examined. In Pecten and Spondylus, however, they have been fully studied (see fig. 145, and explanation).

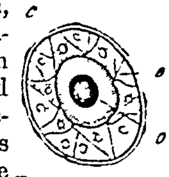

FIG 146.—Otocyst of Cyclas (from Gegenbaur) *c*, capsule, *e*, ciliated cells lining the same, *o*, otolith.

The gonads of Anodon are placed in distinct male and female individuals. In some Lamellibranchs—for instance, the European Oyster and the *Pisidium pusillum*—the sexes are united in the same individual; but here, as in most hermaphrodite animals, the two sexual elements are not ripe in the same individual at the same moment. It has been conclusively shown that the *Ostrea edulis* does not fertilize itself. The American Oyster (*O. virginiana*) and the Portuguese Oyster (*O. angulata*) have the sexes separate, and fertilization is effected in the open water after the discharge of the ova and the spermatozoa from the females and males respectively. In the *Ostrea edulis* fertilization of the eggs is effected at the moment of their escape from the uro-genital groove, or even before, by means of spermatozoa drawn into the sub-pallial chamber by the incurrent ciliary stream, and the embryos pass through the early stages of development whilst entangled between the gill-lamellæ of the female parent (fig. 6). In Anodon the eggs pass into the space between the two lamellæ of the outer gill-plate, and are there fertilized, and advance whilst

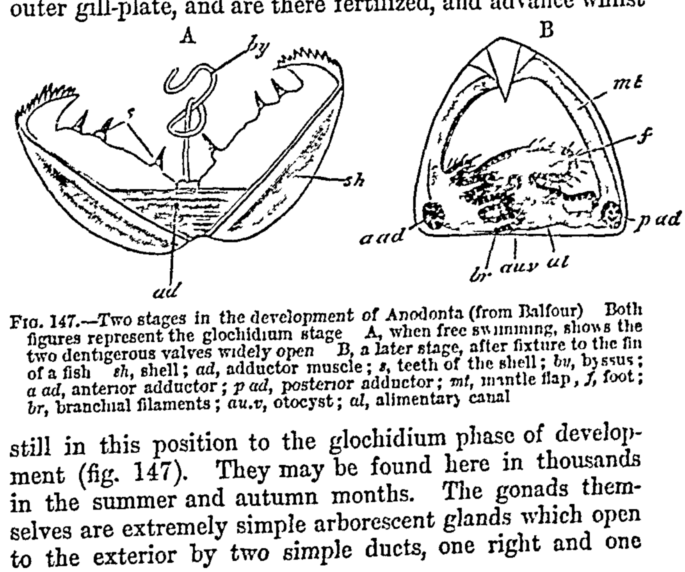

FIG. 147.—Two stages in the development of Anodonta (from Balfour) Both figures represent the glochidium stage A, when free swimming, shows the two dentigerous valves widely open B, a later stage, after fixture to the fin of a fish *sh*, shell; *ad*, adductor muscle; *s*, teeth of the shell; *by*, byssus; *a ad*, anterior adductor; *p ad*, posterior adductor; *mt*, mantle flap; *f*, foot; *br*, branchial filaments; *au.v*, otocyst; *al*, alimentary canal

still in this position to the glochidium phase of development (fig. 147). They may be found here in thousands in the summer and autumn months. The gonads themselves are extremely simple arborescent glands which open to the exterior by two simple ducts, one right and one

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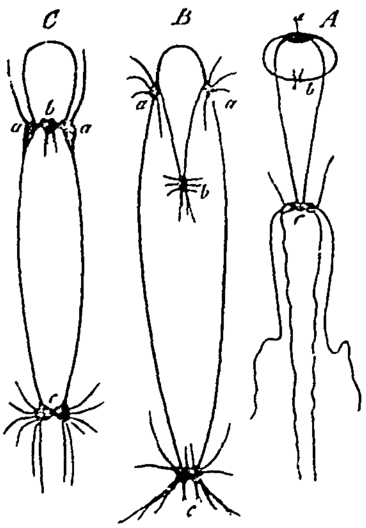

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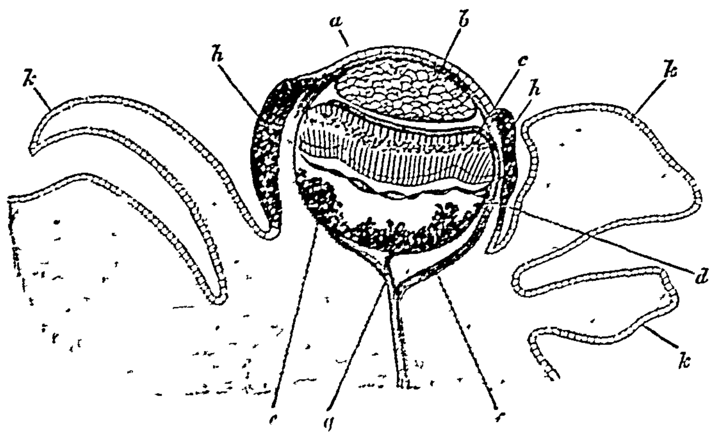

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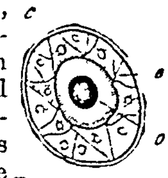

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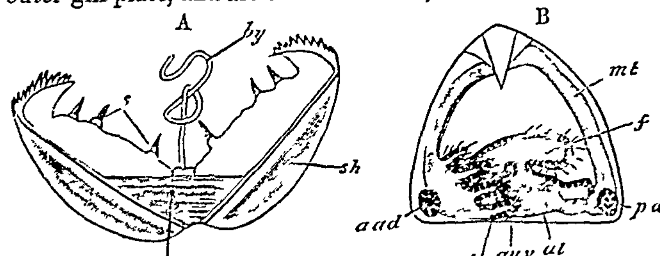

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still in this position to the glochidium phase of development (fig. 147). They may be found here in thousands in the summer and autumn months. The gonads themselves are extremely simple arborescent glands which open to the exterior by two simple ducts, one right and one

The embryonic cells continue to divide, and form an oval vesicle containing liquid (fig. 149); within this, at one pole, is seen the mass of invaginated cells (fig. 150, *hy*). These invaginated cells are the arch-enteron; they proliferate and give off branching cells, which apply themselves (fig. 150, C) to the inner face of the vesicle, thus forming the meso-

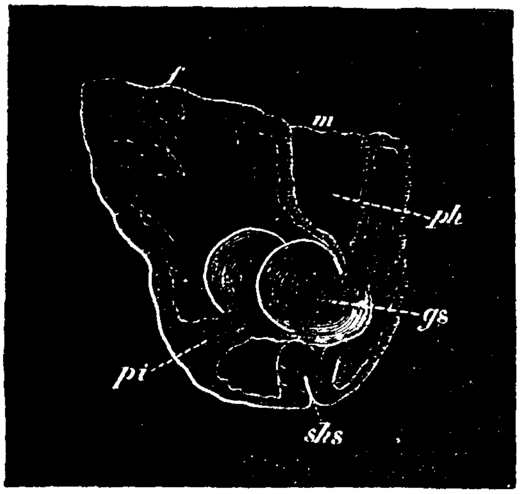

FIG. 152.—Diagram of embryo of Pisidium in the same stage as E in fig. 151. *m*, mouth; *f*, foot; *ph*, pharynx; *gs*, met-enteron; *pi*, rectal peduncle or pedicle of invagination; *shs*, shell-gland. (From Lankester.)

blast or cœlomic outgrowths. The outer single layer of cells which constitutes the surface of the vesicle (fig. 147) is the ectoderm or epiblast or deric cell-layer. The little mass of hypoblast or enteric cell-mass now enlarges, but remains connected with the cicatrix of the blastopore or orifice of invagination by a stalk, the rectal peduncle (fig. 151, A, *rp*). The enteron itself becomes bilobed and is joined by a new invagination, that of the mouth and stomodæum, *ph*. Fig. 151, B shows the origin of the mouth *o*, being a deeper view of the same specimen in the same position which is drawn in fig. 151, A. The mesoblast multiplies its cells, which become partly muscular and partly skeleto-trophic. Centro-dorsally now appears the embryonic shell-gland (fig. 151, C, *sh*). The pharynx or stomodæum is still small, the foot not yet prominent. A later stage is seen in fig. 152, where the pharynx is widely open and the foot prominent. No ciliated velum or præ-oral (cephalic) lobe ever develops. The shell-gland disappears, the mantle-skirt is raised as a ridge (fig. 151, E, *mn*), the paired shell-valves are secreted, the anus opens by a proctodæal ingrowth into the rectal peduncle, and the rudiments of the gills (*br*) and of the nephridia (B) appear (figs. 151, F, and 153, dorsal and lateral views of same stage), and thus the chief organs and general form of the adult are

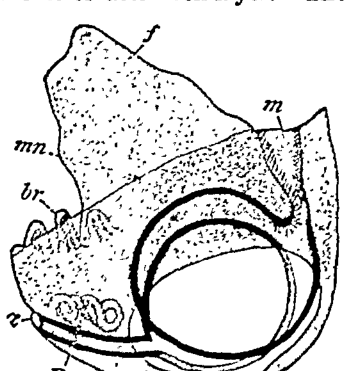

FIG. 153.—Diagram of embryo of Pisidium, in same stage as F in fig. 151 (after Lankester). *m*, mouth; *z*, anus; *f*, foot; *br*, branchial filaments; *mn*, margin of the mantle-skirt; *B*, organ of Bojanus (nephridium). The unshaded area gives the position of the shell-valve.

acquired. Later changes, not drawn here, consist in the growth of the shell-valves over the whole area of the mantle-flaps, and in the multiplication of the gill-filaments and their consolidation to form gill-plates. It is important to note that the gill-filaments are formed one by one *posteriorly*. The labial tentacles are formed late. In the allied genus Cyclas, a byssus gland is formed in the foot and subsequently disappears, but no such gland occurs in Pisidium. The nerve-ganglia and the otocysts probably form from thickenings of the epiblast, but detailed observation on this and other points of histogenesis in the Lamellibranchia is still wanting.

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(E. R. L.)

MOLLUSCOIDS. See BRACHIOPODA and POLYZOA.

MOLOCH, or MOLECH—in Hebrew, with the doubtful exception of 1 Kings xi. 7, always הַמֹּלֶךְ with the article—is the name or title of the divinity which the men of Judah in the last ages of the kingdom were wont to propitiate by the sacrifice of their own children. The phrase employed in speaking of these sacrifices is "to make one's son or daughter pass through fire to the Moloch" (2 Kings xxiii.

The embryonic cells continue to divide, and form an oval vesicle containing liquid (fig. 149); within this, at one pole, is seen the mass of invaginated cells (fig. 150, *hy*). These invaginated cells are the arch-enteron; they proliferate and give off branching cells, which apply themselves (fig. 150, C) to the inner face of the vesicle, thus forming the meso-

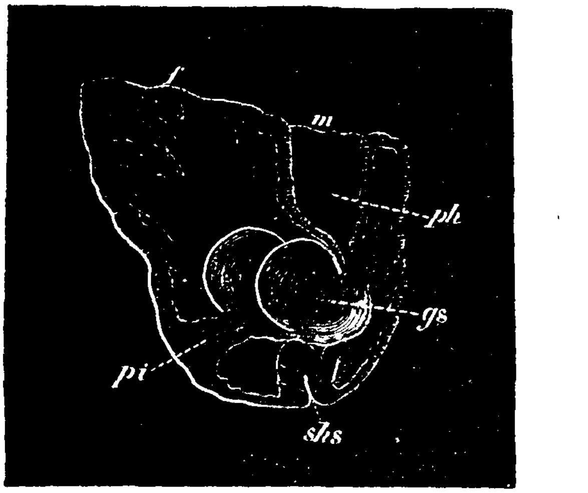

FIG. 152.—Diagram of embryo of Pisidium in the same stage as E in fig. 151. *m*, mouth; *f*, foot; *ph*, pharynx; *gs*, met-enteron; *pi*, rectal peduncle or pedicle of invagination; *shs*, shell-gland. (From Lankester.)

blast or cœlomic outgrowths. The outer single layer of cells which constitutes the surface of the vesicle (fig. 147) is the ectoderm or epiblast or deric cell-layer. The little mass of hypoblast or enteric cell-mass now enlarges, but remains connected with the cicatrix of the blastopore or orifice of invagination by a stalk, the rectal peduncle (fig. 151, A, *rp*). The enteron itself becomes bilobed and is joined by a new invagination, that of the mouth and stomodæum, *ph*. Fig. 151, B shows the origin of the mouth *o*, being a deeper view of the same specimen in the same position which is drawn in fig. 151, A.

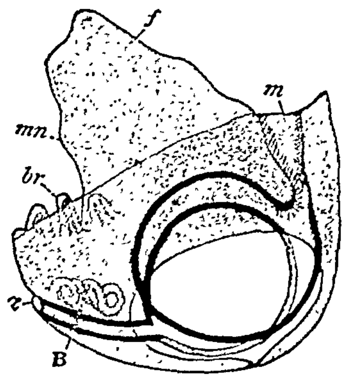

FIG. 153.—Diagram of embryo of Pisidium, in same stage as F in fig. 151 (after Lankester). *m*, mouth; *x*, anus; *f*, foot; *br*, branchial filaments; *mn*, margin of the mantle-skirt; *B*, organ of Bojanus (nephridium). The unshaded area gives the position of the shell-valve.

The mesoblast multiplies its cells, which become partly muscular and partly skeleto-trophic. Centro-dorsally now appears the embryonic shell-gland (fig. 151, C, *sh*). The pharynx or stomodæum is still small, the foot not yet prominent. A later stage is seen in fig. 152, where the pharynx is widely open and the foot prominent. No ciliated velum or præ-oral (cephalic) lobe ever develops. The shell-gland disappears, the mantle-skirt is raised as a ridge (fig. 151, E, *mn*), the paired shell-valves are secreted, the anus opens by a proctodæal ingrowth into the rectal peduncle, and the rudiments of the gills (*br*) and of the nephridia (B) appear (figs. 151, F, and 153, dorsal and lateral views of same stage), and thus the chief organs and general form of the adult are acquired. Later changes, not drawn here, consist in the growth of the shell-valves over the whole area of the mantle-flaps, and in the multiplication of the gill-filaments and their consolidation to form gill-plates. It is important to note that the gill-filaments are formed one by one *posteriorly*. The labial tentacles are formed late. In the allied genus Cyclas, a byssus gland is formed in the foot and subsequently disappears, but no such gland occurs in Pisidium. The nerve-ganglia and the otocysts probably form from thickenings of the epiblast, but detailed observation on this and other points of histogenesis in the Lamellibranchia is still wanting.

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MOLYBDENUM, one of the rarer metallic elements (symbol for atomic weight, Mo = 96; H = 1), occurs in nature chiefly in the two forms of Yellow Lead Ore ($PbOMoO_3$) and Molybdenite (MoS_2). The latter mineral is very similar in appearance and in mechanical properties to graphite or black lead, and, in fact, was long confounded with it chemically, until Scheele in 1778 and 1779 proved their difference by showing that only the mineral now called molybdenite yields a white earth on oxidation. The metallic radical of the earth, after its discovery by Hjelm, was called molybdenum, from μόλυβδος, lead.

By heating molybdenite in a combustion tube in a current of air, we obtain the trioxide MoO_3 (molybdic acid) as a white crystalline sublimate. This substance, when heated to redness in close vessels, fuses without much volatilization into a yellow liquid, which, on cooling, freezes into a crystalline radiated mass of 4·39 specific gravity. It dissolves in 500 parts of cold, and in 960 of hot water. It dissolves readily in aqueous ammonia or alkalies, forming *molybdates*. Like silica, it combines with bases in a great variety of proportions. Of these many salts, an ammonia salt of the composition $3(NH_4)_2O \cdot 7MoO_3 + 4H_2O$ (known in laboratory parlance simply as molybdate of ammonia) is the most important, affording, as it does, the most delicate, characteristic, and widely applicable precipitant for ortho-phosphoric acid. To detect phosphoric acid in any substance soluble in water or nitric acid, add first to a solution of molybdate of ammonia an excess of nitric acid, and then (not too much) of the nitric solution of the phosphate, and keep the mixture at 40° C.; the whole of the phosphoric acid gradually separates out in the shape of a canary-yellow crystalline precipitate of "*phospho-molybdate of ammonia*," of the composition

$$\left.\begin{array}{l}24MoO_3 \cdot P_2O_5 \cdot 3(NH_4)_2O \\ +24MoO_3 \cdot P_2O_5 \cdot 2(NH_4)_2O \cdot H_2O\end{array}\right\} + 16H_2O$$

(according to Gibbs), which is insoluble in the reagent, even in the presence of dilute nitric acid, but soluble in excess of phosphoric acid. By treatment of this complex ammonia salt with aqua regia we can eliminate its acid $24MoO_3 \cdot P_2O_5 \cdot 3H_2O$ as a substance soluble in water and crystallizing from this solution with 59 molecules of water.

This phospho-molybdic acid plays a great part in chemical toxicology, being a generically characteristic precipitant for all (organic) alkaloids, which combine with it, pretty much as ammonia does, into precipitates insoluble in dilute mineral acids. A solution of the acid sufficient for this purpose may be obtained by saturating carbonate of soda solution with molybdic acid, adding phosphate of soda, one part for every five of MoO_3, evaporating to dryness, fusing, dissolving in water, filtering, and adding nitric acid until the liquid becomes yellow.

Metallic molybdenum is obtained by reduction of the trioxide in hydrogen gas at very high temperatures. It is thus obtained in small crystalline granules which are infusible even in the oxy-hydrogen flame. An alloy of the metal with four or five per cent. of carbon (formerly accepted as molybdenum) fuses in the oxy-hydrogen flame into a silver-white metal, of 8·6 specific gravity, which is harder than topaz (Debray).

Analysis.—Molybdenum in all its forms is readily converted into molybdic acid by oxidizing agents, such as nitric acid; or if in non-volatile forms into alkaline molybdate by fusion with carbonate of alkali and nitre. Alkaline molybdate is soluble in water; the solution, on a gradual addition of hydrochloric acid, gives first a white precipitate, which then dissolves in the excess of acid. When a piece of zinc is added to such a solution, the latter, through gradual reduction of its MoO_3 to lower oxides, assumes first a blue, then a green, and lastly a deep blackish-brown colour. Molybdic acid colours the blowpipe flame yellowish green. It dissolves in fused borax, forming a bead which in the oxidizing flame becomes yellow in the heat, but almost colourless on cooling; the reducing flame colours it dark brown, and may cause the separation of brown flakes of MoO_2. Compare CHEMISTRY, vol. v. pp. 541, 542.

MOMBASA, or less correctly MOMBAS, the *Mwita* of the Sawahili, a town on the east coast of Africa, in 4° 4′ S. lat., with the best harbour on all the Zanzibar mainland. The coralline island of which it occupies the eastern portion is 3 miles long by 2½ broad, and lies in the middle of a double inlet of the sea stretching northward into Port Tudor (so called after the English officer who surveyed it) and westward into Port Reitz (after the English resident who died while exploring the Pangani river in 1823). Except at the western end, the coast of the island consists of cliffs from 40 to 60 feet high. In the vicinity of the town palms, mangoes, guavas, baobabs, and cinnamon-trees flourish abundantly, and farther to the west are stretches of virgin forest, the haunt of monkeys, wild hogs, and hyænas. The citadel, originally constructed by Xeixas and Cabrera in 1635, still remains in good condition, "a picturesque yellow pile with long buttressed curtains," but has preserved little of its Portuguese architecture. Of the twenty Portuguese churches which Mombasa once contained, only two or three can be identified. A few of the houses are built of stone, but most of them are mere thatched huts. The population in 1844 was, according to Dr Krapf, from 8000 to 10,000, mostly Wasawahili, but with a considerable number of Arabs and some thirty or forty Banyans. In 1857 Burton estimated the inhabitants at 8000 to 9000, and in 1883 they numbered about 20,000. The Arabs, the Wamwita, and the Wakilindini (the two divisions of the Wasawahili residents, of which the former is the original stock) have each their own chief. In 1875-76 the Church Missionary Society, which made Mombasa one of its stations in 1844, established a settlement for liberated slaves at Freretown (Kisauni) on the mainland, opposite Mombasa. By 1881 it consisted of about 450 persons, of whom about one-fourth were children attending school. The pupils are taught to read both English and Sawahili (*Ch. Miss. Intelligencer*, 1875-76 and 1881). A branch station at Rabbai numbers 600 inhabitants.

Mombasa takes its name from Mombasa in Oman. It is mentioned by Ibn Batúta in 1331 as a large place, and at the time of Vasco da Gama's visit it was the residence of Calicut Banyans and Christians of St Thomas, and the seat of considerable commerce. The "king" of the city, however, tried to entrap Da Gama, and with this began a series of troubles which give full force to the native name *Mwita* (war). The principal incidents are the capture and burning of the place by Almeyda (1505), Nuno da Cunha (1529), and Duarte de Menezes (1587)—this last as a revenge for its submission to the sultan of Constantinople—the building of the Portuguese fort (1594), the revolt of Yusuf ibn Ahmed (1631), the erection of the Portuguese citadel (1635), the five years' siege by the imam of Oman (1660-65), and the final expulsion of the Portuguese (1698). In 1823 the Mazara family, who had ruled in Mombasa from the early part of the 18th century, placed the city under British protection; but Britain soon withdrew, and left the place to be bombarded and captured by Sayyid Said of Zanzibar, who was obliged to make repeated attacks between 1829 and 1833, and only got possession in 1834 by treachery. A revolt against Zanzibar in 1875 was put down by British assistance.

See Capt. W. F. W. Owen, *Narrative*, &c. (1833); Capt. Thomas Boteler, *Narrative*, &c. (1835); Guillain, *Voyage*, (Paris, 1856); Krapf, *Travels*, (1860); Burton, *Zanzibar*, (1872).

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$$\left.\begin{array}{l} 24MoO_3 \cdot P_2O_5 \cdot 3(NH_4)_2O \\ +24MoO_3 \cdot P_2O_5 \cdot 2(NH_4)_2O \cdot H_2O \end{array}\right\} + 16H_2O$$

(according to Gibbs), which is insoluble in the reagent, even in the presence of dilute nitric acid, but soluble in excess of phosphoric acid. By treatment of this complex ammonia salt with aqua regia we can eliminate its acid $24MoO_3 \cdot P_2O_5 \cdot 3H_2O$ as a substance soluble in water and crystallizing from this solution with 59 molecules of water.

This phospho-molybdic acid plays a great part in chemical toxicology, being a generically characteristic precipitant for all (organic) alkaloids, which combine with it, pretty much as ammonia does, into precipitates insoluble in dilute mineral acids. A solution of the acid sufficient for this purpose may be obtained by saturating carbonate of soda solution with molybdic acid, adding phosphate of soda, one part for every five of MoO_3, evaporating to dryness, fusing, dissolving in water, filtering, and adding nitric acid until the liquid becomes yellow.

Metallic molybdenum is obtained by reduction of the trioxide in hydrogen gas at very high temperatures. It is thus obtained in small crystalline granules which are infusible even in the oxy-hydrogen flame. An alloy of the metal with four or five per cent. of carbon (formerly accepted as molybdenum) fuses in the oxy-hydrogen flame into a silver-white metal, of 8·6 specific gravity, which is harder than topaz (Debray).

Analysis.—Molybdenum in all its forms is readily converted into molybdic acid by oxidizing agents, such as nitric acid; or if in non-volatile forms into alkaline molybdate by fusion with carbonate of alkali and nitre. Alkaline molybdate is soluble in water; the solution, on a gradual addition of hydrochloric acid, gives first a white precipitate, which then dissolves in the excess of acid. When a piece of zinc is added to such a solution, the latter, through gradual reduction of its MoO_3 to lower oxides, assumes first a blue, then a green, and lastly a deep blackish-brown colour. Molybdic acid colours the blowpipe flame yellowish green. It dissolves in fused borax, forming a bead which in the oxidizing flame becomes yellow in the heat, but almost colourless on cooling; the reducing flame colours it dark brown, and may cause the separation of brown flakes of MoO_2. Compare CHEMISTRY, vol. v. pp. 541, 542.

MOMBASA, or less correctly MOMBAS, the *Mvita* of the Sawahili, a town on the east coast of Africa, in 4° 4′ S. lat., with the best harbour on all the Zanzibar mainland. The coralline island of which it occupies the eastern portion is 3 miles long by 2½ broad, and lies in the middle of a double inlet of the sea stretching northward into Port Tudor (so called after the English officer who surveyed it) and westward into Port Reitz (after the English resident who died while exploring the Pangani river in 1823). Except at the western end, the coast of the island consists of cliffs from 40 to 60 feet high. In the vicinity of the town palms, mangoes, guavas, baobabs, and cinnamon-trees flourish abundantly, and farther to the west are stretches of virgin forest, the haunt of monkeys, wild hogs, and hyænas. The citadel, originally constructed by Xeixas and Cabrera in 1635, still remains in good condition, "a picturesque yellow pile with long buttressed curtains," but has preserved little of its Portuguese architecture. Of the twenty Portuguese churches which Mombasa once contained, only two or three can be identified. A few of the houses are built of stone, but most of them are mere thatched huts. The population in 1844 was, according to Dr Krapf, from 8000 to 10,000, mostly Wasawahili, but with a considerable number of Arabs and some thirty or forty Banyans. In 1857 Burton estimated the inhabitants at 8000 to 9000, and in 1883 they numbered about 20,000. The Arabs, the Wamwita, and the Wakilindini (the two divisions of the Wasawahili residents, of which the former is the original stock) have each their own chief. In 1875-76 the Church Missionary Society, which made Mombasa one of its stations in 1844, established a settlement for liberated slaves at Freretown (Kisauni) on the mainland, opposite Mombasa. By 1881 it consisted of about 450 persons, of whom about one-fourth were children attending school. The pupils are taught to read both English and Sawahili (*Ch. Miss. Intelligencer*, 1875-76 and 1881). A branch station at Rabbai numbers 600 inhabitants.

Mombasa takes its name from Mombasa in Oman. It is mentioned by Ibn Batúta in 1331 as a large place, and at the time of Vasco da Gama's visit it was the residence of Calicut Banyans and Christians of St Thomas, and the seat of considerable commerce. The "king" of the city, however, tried to entrap Da Gama, and with this began a series of troubles which give full force to the native name *Mvita* (war). The principal incidents are the capture and burning of the place by Almeyda (1505), Nuno da Cunha (1529), and Duarte de Menezes (1587)—this last as a revenge for its submission to the sultan of Constantinople—the building of the Portuguese fort (1594), the revolt of Yusuf ibn Ahmed (1631), the erection of the Portuguese citadel (1635), the five years' siege by the imam of Oman (1660-65), and the final expulsion of the Portuguese (1698). In 1823 the Mazara family, who had ruled in Mombasa from the early part of the 18th century, placed the city under British protection; but Britain soon withdrew, and left the place to be bombarded and captured by Sayyid Said of Zanzibar, who was obliged to make repeated attacks between 1829 and 1833, and only got possession in 1834 by treachery. A revolt against Zanzibar in 1875 was put down by British assistance.

See Capt. W. F. W. Owen, *Narrative, &c.* (1833); Capt. Thomas Boteler, *Narrative, &c.* (1835); Guillain, *Voyage,* (Paris, 1856); Krapf, *Travels,* (1860); Burton, *Zanzibar,* (1872).

were urged on to still greater severity of life when the rapid progress of Christianity brought large numbers of merely nominal converts in, whose practice fell too conspicuously below their profession. The desire of protest against such a state of things led to the gradual separation of the devotees into a kind of order within the main body, and to their actual withdrawal from habitual intercourse with their less strict fellows, which led in turn to their departure from the towns into more secluded places, even before any formal conception of the monastic life had shaped itself in their minds. But the first glimpse obtainable of the "common life," and that only an indistinct one, is in the New Testament, and applies to women alone. There is mention in the pastoral epistles (1 Tim. v. 9-12) of a class of widows, apparently not as mere recipients of relief, but as constituting an ecclesiastical grade; while in Acts ix. 39 it appears as if a number of women belonging to this order were united in some kind of community under the headship of Dorcas, for the narrative rather implies that they were her assistants in making clothing for the poor than themselves the objects of her bounty. This conjecture receives some confirmation from the mention of "the virgins who are called widows" (τὰς παρθένους τὰς λεγομένας χῆρας) in the shorter recension of the Ignatian Epistle to the Smyrnæans, and from the statement of Athanasius, that Anthony, when himself about to begin the solitary life which he is regarded as having instituted, first placed his sister in a convent of virgins (παρθενῶνα),—facts which prove the organization of women at an earlier date in community life than of men, and lend some probability to the notion that it may have begun very soon indeed, especially when the prominence given to the virgins as a separate and seemingly long-established order in the church by such early writers as Tertullian and Cyprian is borne in mind.

Two other causes must be taken into account as tending to stimulate monachism when once it began. First is the theological opinion, early formulated, and never since without many advocates, that two distinct standards of life and holiness are set forth in the gospel: that of precept, and that of "counsels of perfection,"—the former binding all Christians without exception, the latter being voluntary, and merely offered for acceptance to such as aim at especial sanctity. The second, and even more powerful, agent was Gnosticism, not only in its earlier forms and in the kindred spirit of Montanism, but still more in its Manichæan development, when its dualism led to exaggeration of the antagonism between flesh and spirit, and the human body was regarded no longer as a servant to be trained, but as an enemy to be crushed and beaten down with unrelenting hostility. But in every age of monachism, from the earliest to the latest, social disorders and insecurity have proved the chief feeders of the cloister, never widely popular in times of healthy and orderly national life, but eagerly resorted to as a place of shelter from social turbulence.

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Lay in their origin, and for the greater part of their earlier history having but rarely ecclesiastics amongst them (a single priest ordained for each monastery to minister to its inmates being the utmost allowed for a considerable time), they were not subject to the same strict inspection and discipline as the clergy, in case a whole community chose to disregard its rule; though of course it was easy to deal with an offender who had the tone of his monastery against him. The clergy were subject to the direct control of the bishops, and many disciplinary canons of councils laid down rules for their conduct; but this was not the case with the monks for a considerable time—nor indeed ever effectively in the East—and their lay character gave them practical independence of any authority external to their abbot. And, despite the stringency of the monastic rule itself, which, even before actual vows began to be introduced (probably on the recommendation of Basil), always involved during compliance with it the three engagements to the observance of poverty, chastity, and obedience, which make up the staple of the monastic principle, and though pains were taken to exclude unfit applicants (such as criminals, slaves who had fled for reasons other than ill-treatment, or persons who had kindred dependent on them), while a long probation was exacted from all who were accepted, yet it was impossible that more than a small proportion of the many thousands who flocked in during the first enthusiasm for the new movement should have had any real sympathy with the restraints and aspirations of such a mode of life. Severe asceticism operates differently on different natures, and while there are some whom it does but discipline and refine there are more whom it tends to coarsen and to brutalize, even apart from the many whom it is apt to affect with morbidness, if not actual insanity. And it is unquestionable that vast numbers of those who entered on the monastic life came from the poorer classes, in search of some less toilsome mode of existence than they had previously led, preferring the contemplative societies, wherein almost no labour, certainly none of a severe and trying cast, was practised, to those where agriculture and other active employments, requiring more energy than mat and basket weaving, were enjoined. Such men, uneducated and undisciplined, were liable to be thrown entirely out of gear by the complete revolution in their mode of life,—especially when the community they joined was not only contemplative, but situated in some place where the ungrateful soil made tillage nearly impracticable, and the vast numbers crowded together were far too numerous for any tasks which could be assigned them. From the bosom of such societies came not only single examples of exaggerated spiritual pride, bitter fanaticism, avaricious greed of the scanty articles whose usufruct was permitted, fierce sensuality, and wild religious delusions, but they gave birth to companies like the *βοσκοί*, or "grazing monks," of Mesopotamia and Palestine, who roved about, shelterless and nearly naked, as Sozomen and Evagrius tell us, in the mountains and deserts, grovelling on the earth, and browsing like cattle on the herbs they casually found; and to those fierce bands of Nitrian and Syrian ascetics who, reared in the narrowest of schools, treated any divergence from their own standard of opinion as a crime which they were entitled to punish in their own riotous fashion, two instances of which have left an indelible brand on their history—the murder of Hypatia in Alexandria, and that of the patriarch Flavian at the Robber Synod of Ephesus. An equally singular, but more sporadic and temporary, form of asceticism was that of the Stylites or Pillar-hermits (*στυλῖται, κιονῖται*), who followed a fashion first set by Simeon, a Syrian monk who spent almost half of the 5th century on the summit of a column 60 feet in height. This unwonted kind of austerity at first gave rise to strong objections, even from hermits themselves, and a messenger was sent to Simeon, bidding him in the name of a synod of bishops to descend from his pillar, but with instructions to permit him to remain if he showed himself ready to comply. Such proved to be the case; and, having thus assured themselves that he was not influenced by spiritual pride, they left him to follow his own devices. And we have the direct personal testimony of the wise and temperate Theodoret that he exercised a strong and salutary influence over the nomadic Saracen tribes, converting many hundreds and even thousands to Christianity, besides being the shrewd and trusted adviser, not only of the peasants who flocked to him for counsel, but of Arab princes, Persian kings, and even Roman emperors. He cannot be judged, therefore, by ordinary standards, and it is more than likely that a less extraordinary mode of life would have given him less power for good; but he is the only eminent figure in the class to which he belongs, and the fashion he set may be said to have died out with his namesake, the younger Simeon, a century later. Even when the healthier side of monachism as it appeared in Egypt and Syria is dwelt upon, and the fullest weight is allowed to the contemporary pictures drawn by great Christian writers of the monasteries as schools of a philosophy truer and purer than that of the Porch or the Academy, as places where the equality and brotherhood, merely dreamed of as unrealizable fancies in the outer world, could be seen in living action—where children, deserted by their parents or otherwise orphaned, were carefully reared—where the sick were lovingly tended—where calmness, piety, and self-forgetfulness were the rule of all,—it must be confessed that the complaint of the Government, embodied in the hostile legislation of the emperor Valens in 373, subjecting monks to the conscription (which drew forth an indignant protest from Chrysostom), that monachism was injurious to society and to the healthy condition of civil life by draining off so large a fraction of the population into the backwater of the cloister, was perfectly well founded. And no small part of the overthrow of Christianity in Egypt and Syria by Islam is due to the practical withdrawal of all the devout from family and public life, leaving no spiritual energy to cope with the Koran in the towns and villages whither the conquering Arabs came to settle and proselytize.

The history of monachism in the West is far more varied, chequered, and interesting than in the East. It takes its beginning from the visit of Athanasius to Rome in 340, during his second term of exile, when he brought with him his *Life of St Anthony*, and pressed his example on the Roman Christians who mourned as patriots, not less than as devotees, over the lax and enervated habits of society. The popular imagination was caught at once, and not only was the basis of monachism successfully laid in Rome itself, but Eusebius of Vercelli introduced it

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And we have the direct personal testimony of the wise and temperate Theodoret that he exercised a strong and salutary influence over the nomadic Saracen tribes, converting many hundreds and even thousands to Christianity, besides being the shrewd and trusted adviser, not only of the peasants who flocked to him for counsel, but of Arab princes, Persian kings, and even Roman emperors. He cannot be judged, therefore, by ordinary standards, and it is more than likely that a less extraordinary mode of life would have given him less power for good; but he is the only eminent figure in the class to which he belongs, and the fashion he set may be said to have died out with his namesake, the younger Simeon, a century later. Even when the healthier side of monachism as it appeared in Egypt and Syria is dwelt upon, and the fullest weight is allowed to the contemporary pictures drawn by great Christian writers of the monasteries as schools of a philosophy truer and purer than that of the Porch or the Academy, as places where the equality and brotherhood, merely dreamed of as unrealizable fancies in the outer world, could be seen in living action—where children, deserted by their parents or otherwise orphaned, were carefully reared—where the sick were lovingly tended—where calmness, piety, and self-forgetfulness were the rule of all,—it must be confessed that the complaint of the Government, embodied in the hostile legislation of the emperor Valens in 373, subjecting monks to the conscription (which drew forth an indignant protest from Chrysostom), that monachism was injurious to society and to the healthy condition of civil life by draining off so large a fraction of the population into the backwater of the cloister, was perfectly well founded. And no small part of the overthrow of Christianity in Egypt and Syria by Islam is due to the practical withdrawal of all the devout from family and public life, leaving no spiritual energy to cope with the Koran in the towns and villages whither the conquering Arabs came to settle and proselytize.

The history of monachism in the West is far more varied, chequered, and interesting than in the East. It takes its beginning from the visit of Athanasius to Rome in 340, during his second term of exile, when he brought with him his *Life of St Anthony*, and pressed his example on the Roman Christians who mourned as patriots, not less than as devotees, over the lax and enervated habits of society. The popular imagination was caught at once, and not only was the basis of monachism successfully laid in Rome itself, but Eusebius of Vercelli introduced it

of the introduction of monachism there, all that is certain being that it had made its footing good before 380, the date of a council of Saragossa (Cæsaraugusta) which forbade priests to assume the monkish habit. Still more obscurity hangs over the first establishment of monachism in Britain, as to which no trustworthy records have come down to us, though all probability points to its importation from Gaul in some variety of the Pachomian rule; while Germany did not receive the institute till the following century.

It must not be supposed, however, that the principle of monachism met with no opposition in the course of its progress. Apart from the opposition of those who disliked it precisely for its merits, for its protest against the dissolute morals and enervated habits of a luxurious and rotting society, and for the manner in which it won to itself many of the noblest and most promising of the young and ardent of both sexes, and without taking into account the more reasonable objections of statesmen, there were not lacking warnings of the dangers attending exaggerations of the principle of monachism, uttered by some of its most eminent upholders. Augustine's sharp censures have been already mentioned, and to them may be added the decrees of the council of Gangra in 363, or thereabouts, which anathematize those who adopt a celibate life on the ground that marriage is evil, who wear a peculiar dress as a mark of holiness, condemning such as use ordinary clothing, or who desert their parents or children dependent on them under the plea of desiring to lead an ascetic life. So, too, the great Chrysostom, himself a warm advocate of monachism, found himself obliged to teach his flock the sanctity of Christian family life, and the truth that there was often as much selfishness as piety in retirement to a hermitage from the cares and duties of society. These arguments and decisions were, however, aimed only at abuses and exaggerations of the monastic idea. It remained for Jovinian and Vigilantius to assail the actual principle. Their writings have not survived, and we can judge of their arguments only from the account given of them by their chief opponent Jerome, whose eminent gifts, however, did not include either moderation or controversial fairness, so that it is not safe to assume that we have all their case before us. As regards Vigilantius, he accurately represents the Puritan type of mind protesting against the external part of the popular religion of his day, often with good reason, but also showing equal intolerance for harmless, if not useful, practices; so that his condemnation of monachism is only part of his general objection to the temper of his time. But Jovinian's objections seem to have gone deeper. He had been himself a monk (and indeed never resumed secular life), but he disputed absolutely the thesis that any merit lay in monachism, celibacy, fasting, and asceticism considered in themselves, save in so far as they contributed to foster the Christian temper and life, which might and did flourish equally, he urged, under quite different conditions, while it was by no means unfrequent for spiritual pride, if not Manichæan error, to lay hold of those who devoted themselves to the ascetic profession. This was, in fact, going very little further than Chrysostom had done, or than Nilus did a short time later. But Jovinian's divergence from the standard of his day was not confined to practical questions; it extended to theological doctrines also, and accordingly his strictures on monachism, probably more incisive and less qualified than those of its other critics, were involved in his condemnation as a heretic by synods at Rome and Milan in 390. The reaction, of which he may be regarded as the mouthpiece rather than as the sole representative, was thus effectually crushed, and that for centuries. And though Jovinian is undoubtedly more in accord than his opponents with the modern temper on the subject of monachism, and while it may be allowed that his teaching might have been a useful corrective in Eastern Christendom, where family life was all but overborne by asceticism, yet the impartial historian must admit that his success would have been an irreparable misfortune for civilization in the West. Such a dispassionate estimate of asceticism as his, if widely entertained, would have been fatal to the spread of monachism, and thus one of the most important conservative and statical forces in the preservation of the older culture, one of the most powerful dynamical forces in reducing the chaotic materials of early mediæval society to order and coherence, would have been lost to Europe; nor is it easy to conjecture what effectual substitute could have taken its place. As it was, the movement was not checked for a moment by this partial reaction; and not only did the older communities thrive and spread during the 5th and early 6th centuries, but new ones were established,—chief among which stand those of Cæsarius of Arles and of Donatus of Besançon in southern Gaul, that of Isidore of Seville in Spain, and the early Celtic code, of which only traditional fragments survive, but which seems in Britain to have been strongly affected by tribal influences, so that a monastery was often recruited from a single clan, and the abbacy became hereditary in the family of the chieftain, a fact which is noticeable even in the succession of the abbots of Iona, who for ten elections after Columba were of his family in the tribe of Conall Gulban.[1]

But, swiftly as monachism spread in Europe during the breaking-up of the Western empire, some of the causes which hastened its progress also tended to its rapid decay. The disturbed state of society, and, in particular, the prevalence of petty warfare, drove many thousands of persons to seek a quiet refuge in the cloister without any more directly religious motive. When once there, they found in every place some rule in force which was either imported directly from Egypt or Syria, or else, like that of Cæsarius, modelled on Eastern lines, and therefore ill suited to the severer climate of Europe and the more active habits of the people. The austerities were thus too oppressive for general observance, and the result was a widespread neglect of rules which continued nominally in force, while at the same time the very monks who had ceased to keep them laid claim to special sanctity on the pretence of their strict way of life. The time was ripe for a reform, or rather for a wholly new departure in the shape of a rule devised to meet Western needs, and not merely adapted more or less clumsily from Oriental asceticism. The fitting man to accomplish this difficult task appeared in the person of Benedict of Nursia, author of the most famous of all monastic codes. Born of a respectable family about 480, he adopted the ascetic life at fourteen in a cave near Subiaco, not far from Rome, where he remained for three years, at the expiration of which he was chosen abbot of a neighbouring convent, then in a very relaxed state. His rule proved too stern for his new subjects, who attempted to poison him, whereupon he resigned his office and returned to Subiaco, around which he soon erected twelve monasteries, each peopled by an abbot and twelve monks. Fresh attempts on his life and on the discipline of his society drove him out again in the year 528, when he fixed his dwelling at Monte Cassino, the place where his celebrated rule was drafted in the following year, and which has ever since prided itself on its rank as the cradle of the Benedictine Order and the premier abbey of Western Christendom. The famous institute which he devised

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If he persevere, he is returned to the novice-house for six months' further probation, after which the rule is again read to him as before, and yet a third time after a further term of four months. Not till he has surmounted this final ordeal can he be admitted into the community, and before that is done he must divest himself of his property, either giving it to the poor, or making a deed of gift to the monastery. Then he is allowed to sign the act of profession, including the vow of stability, which he is to lay with his own hand on the altar. Chapter lix. provides for the dedication of young children, noble or poor, by their parents to the monastic life, and requires a promise from the latter never to endow the oblate with any property, directly or in trust, though they may give to the monastery if they please and reserve the life-income to themselves. Chapter lx. regulates the position of priests who desire to live in the monastery. 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If he misbehave, he is to be reported to the bishop, and if continuing to misconduct himself, shall be expelled,—only, however, in case of obstinate disobedience to the rule. Chapter lxiii. lays down rules for the gradation of rank in the community, and warns the abbot against arbitrary government. Chapter lxiv. allows the abbot to be chosen either by the common consent of the whole community, or by a select electoral committee; and the lowest in standing may be chosen, if fit. In the event of a bad choice, the bishop of the diocese, the neighbouring abbots, or even the neighbouring laity, if having reason to think the election made for the purpose of keeping up abuses, may annul it and appoint another superior. Chapter lxv. speaks of the mischief occasioned in many monasteries by the rivalry of the provost or prior with the abbot, and advises that no such officer be appointed; yet, if the circumstances of the place need one, the abbot may name a brother to the post, but he is to be as entirely subject to the abbot as any other monk, and may be admonished, deposed, or expelled for misconduct. Chapter lxvi. directs the appointment of a porter to answer at the gate, and further recommends that every house shall have its own well, mill, garden, bakery, and handicraftsmen, to avoid the need of intercourse with the outer world. Chapter lxvii. directs that no monk shall quit the cloister without leave of the abbot, and that, on the return of any from a journey, they are to beg the prayers of the community for any faults they have committed during their absence, and are forbidden to speak of what they have heard or seen outside. 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Chapter lxxii. is a brief exhortation to zeal; and chapter lxxiii. a note to the effect that the Benedictine rule is not offered as an ideal of perfection, or even as equal to the teachings of Cassian and Basil, but for mere beginners in the spiritual life, who may thence proceed further.

It has been necessary to make this detailed analysis of the rule, because no mere summary of its general scope conveys an adequate notion of it; and it plays so important a part in the history of European civilization that it is expedient to obtain a clear idea of its details as well as of its main outlines. The first peculiarity in it meriting attention is the absence of any severe austerities. Plain and bare as the food and lodging appear if tested by modern notions, yet it is to be remembered that what is called "comfort" is a wholly recent idea, and even still scarcely familiar, it may almost be said, out of Great Britain and its colonies. The scale of living appointed by the rule secures a greater abundance of the necessaries of life, not only than was at all common amongst the Italian poor of the 6th century, but than is to be found amongst the humbler peasantry of any European country at the present day; while even the excluded superfluities entered but little into the habits of any save the very wealthy. Next, high thinking—the highest thought of the time—was united with this plain living, as the considerable stress laid upon reading attests. To this part of the code is due the great service performed by the Benedictines, both in the erection of schools, and in the preservation of almost all the remains of ancient Latin literature which have come down to us. It made it not only possible but easy for them to become a learned order, and it is a very imperfect estimate of the stride forward in this provision which Milman makes, when he views the injunctions as to reading in the mere light of expedients to fill up time somehow. If it were so, the hours for reading would have been fewer, shorter, and more occasional, merely rounding off the intervals between times of labour; but they are just as prominent and nearly as long as these. It is true that Benedict, whose own education had been abruptly broken off by his early retreat from Rome, did not specifically enjoin the pursuit of learning on his monks; but they borrowed the idea at once from his contemporary, the celebrated Cassiodorus, the real founder of monastic learning, of which his monastery of Viviers in Bruttium is the first known school. But the most valuable feature of the rule is the position of dignity which it assigns to work. It is scarcely possible to realize at the present day the dishonour into which toil of all kinds had sunk in the days of Benedict. Not only had the institution of slavery degraded many kinds of occupation, but the gradual disappearance from Italy of the yeoman class, ruined and exiled by the concentration of great estates (*latifundia*), or slain in the ceaseless battles of competitors for empire or of barbarian invaders, left few save serfs and bondsmen to till the soil, while the military habits of the invading tribes led them to contemn any life except that of a warrior. It is the special glory of Benedict that he taught the men of his day that work, sanctified by prayer, is the best thing which man can do, and the lesson has never been wholly lost sight of since.

Spread and influence of the Benedictine order.

The new institute spread with even more astonishing rapidity than the earlier monachism which it practically supplanted in the West, and its history thenceforward is, with one important exception, that of Western conventual life for some centuries. Moreover, besides marking the close of the first or tentative era of monachism, when all kinds of crude essays and experiments were being made,

merely ruling that in temperate places a cowl and tunic, thick in winter and thin in summer, with a scapular (a sleeveless woollen garment passed over the head, and falling down over the breast and back) for work hours, as also shoes and stockings, all of the ordinary country make and cheapest kind, shall suffice. Each monk is to have a change of these garments, to allow of washing, and yet another for use when sent on a journey, to be of rather better materials, and to be kept in the general wardrobe when not in actual wear. The old clothes are to be given up when new ones are served out, and are to be laid by in the wardrobe for the poor. A straw mattress, blanket, quilt, and pillow are to be furnished for each bed; and in addition the abbot is to give every monk a knife, a pen, a needle, a handkerchief, and tablets. 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It has been necessary to make this detailed analysis of the rule, because no mere summary of its general scope conveys an adequate notion of it; and it plays so important a part in the history of European civilization that it is expedient to obtain a clear idea of its details as well as of its main outlines. The first peculiarity in it meriting attention is the absence of any severe austerities. Plain and bare as the food and lodging appear if tested by modern notions, yet it is to be remembered that what is called "comfort" is a wholly recent idea, and even still scarcely familiar, it may almost be said, out of Great Britain and its colonies. The scale of living appointed by the rule secures a greater abundance of the necessaries of life, not only than was at all common amongst the Italian poor of the 6th century, but than is to be found amongst the humbler peasantry of any European country at the present day; while even the excluded superfluities entered but little into the habits of any save the very wealthy. Next, high thinking—the highest thought of the time—was united with this plain living, as the considerable stress laid upon reading attests. To this part of the code is due the great service performed by the Benedictines, both in the erection of schools, and in the preservation of almost all the remains of ancient Latin literature which have come down to us. It made it not only possible but easy for them to become a learned order, and it is a very imperfect estimate of the stride forward in this provision which Milman makes, when he views the injunctions as to reading in the mere light of expedients to fill up time somehow. If it were so, the hours for reading would have been fewer, shorter, and more occasional, merely rounding off the intervals between times of labour; but they are just as prominent and nearly as long as these. It is true that Benedict, whose own education had been abruptly broken off by his early retreat from Rome, did not specifically enjoin the pursuit of learning on his monks; but they borrowed the idea at once from his contemporary, the celebrated Cassiodorus, the real founder of monastic learning, of which his monastery of Viviers in Bruttium is the first known school. But the most valuable feature of the rule is the position of dignity which it assigns to work. It is scarcely possible to realize at the present day the dishonour into which toil of all kinds had sunk in the days of Benedict. Not only had the institution of slavery degraded many kinds of occupation, but the gradual disappearance from Italy of the yeoman class, ruined and exiled by the concentration of great estates (*latifundia*), or slain in the ceaseless battles of competitors for empire or of barbarian invaders, left few save serfs and bondsmen to till the soil, while the military habits of the invading tribes led them to contemn any life except that of a warrior. It is the special glory of Benedict that he taught the men of his day that work, sanctified by prayer, is the best thing which man can do, and the lesson has never been wholly lost sight of since.

Spread and influence of the Benedictine order.

The new institute spread with even more astonishing rapidity than the earlier monachism which it practically supplanted in the West, and its history thenceforward is, with one important exception, that of Western conventual life for some centuries. Moreover, besides marking the close of the first or tentative era of monachism, when all kinds of crude essays and experiments were being made,

merely over his monks, as in other rules, but over bishops also, whose office was simply that of ordaining such as were to be promoted to holy orders;[1] they had no territorial jurisdiction as rulers, because the monastery, not the diocese, was the primary local unit in Celtic Christianity, and thus a great founder or abbot was of more account and power than a bishop. Another famous pupil of Irish monachism, Columbanus, trained at Benchor along with his companion Gallus, exercised a powerful influence on the religious life of his time (543-615), not only as the founder of important monasteries at Luxeuil, Fontenay, and Bobbio, and as scholar and missionary, but also as the author of a rule, more severe both in its provisions and in its penalties than the Benedictine, with which it disputed for a considerable time the first place, and which it might very probably have displaced, had not the Benedictine institute, as of Italian origin, found that favour at Rome which a Celtic code, bearing more than one trace of divergence from Latin usages, could scarcely expect. With the mention of another prominent name in the list of distinguished Celtic reformers and missionaries, that of Fursey, abbot of Lagny near Paris (*c.* 650), we close this sketch of the Celtic movement in the 6th and 7th centuries, merely adding that its extent and influence may be partly estimated from the number of monasteries founded in England and various parts of the Continent by Irish monks, and the list of Celtic saints recoverable from the different martyrologies and similar records. The former amount to more than one hundred; the latter to nearly three hundred.

Returning to the Benedictines, the most important event in their history after the consolidation of their institute was the favour they received from Gregory the Great, himself once a monk, who set himself to reform monastic discipline, then at a very low ebb save where the new foundation was at work. He enacted several regulations for the better government of monasteries, such as prohibiting the admission of any persons under eighteen, exacting two years' novitiate, enforcing inclosure, visiting relinquishment of monachism with imprisonment for life, and finally, in the Lateran synod of 601, exempting monasteries in all cases from the jurisdiction of bishops (a measure due, it appears, to episcopal misconduct and oppression rather than to monastic ambition), thereby abolishing the measure of control which the eighth canon of Chalcedon and the legislation of Justinian I. in 535 had left in the hands of the diocesan, and leaving only the still surviving check, that the bishop's consent was required for the erection of any new monastery. The mission of the monk Augustine to England in 596 was, however, destined to produce more immediate and fortunate results than this piece of legislation. It brought Latin monachism into a part of Britain whence Welsh monachism had been long extirpated, and though little success attended the original foundation at Canterbury, yet two other houses were destined to be the cradles of great things. Jarrow-on-Tyne, founded by Benedict Biscop, trained the illustrious Bede, to whom is due the monastic school of York, which in its turn sent out Alcuin to reconstitute European learning under the fostering hand of Charlemagne; Nutcell in Hampshire reared Boniface to be the apostle of Germany, and founder of one of the most celebrated and powerful monasteries of the Middle Ages, that of Fulda. Nevertheless, decline set in very soon, and the 8th century was a time of deterioration amongst both the seculars and the regulars. To amend the former, Chrodegang, bishop of Metz, instituted in 760 an order of Canons Regular, living by a rule carefully based on and adapted from the Benedictine, with the bishop as abbot, the archdeacon as prior, and with a general likeness in all the details of community life, except that there was no obligation to poverty, and the canons were allowed to enjoy any private property and such fees as they might receive for the performance of religious rites. This rule became extremely popular, was sanctioned by the council of Aix-la-Chapelle in 816, and was adopted in most cathedrals of France, Germany, and Italy within fifty years after, besides making some way in England also. It prevailed till the institute of the Austin Canons was substituted for it. And, as regards the laxity amongst regulars at this time, there is extant a very interesting letter from Bede addressed to Ecgberht, archbishop of York, calling his attention to the excessive number of monasteries in northern England which were conducted without a rule, and were often merely fictitious institutions, founded by laymen with the object of obtaining charters of privilege which would exempt them from civil and military burdens,—such laymen then assuming, without warrant, the title and powers of abbots, and filling their houses either with monks expelled from their own societies, or with lay retainers induced to receive the tonsure and promise obedience. Bede calls on the archbishop to convene a synod and institute a visitation for the correction of these abuses. The cause of the decline of the monasteries is to be sought in their popularity, which brought them great estates and other kinds of wealth, leading to the relaxation of the vow of poverty, which was interpreted as merely forbidding individual property; in the growth of pluralities; and in yet another cause which at first does not seem to lead in the same direction—the growing custom of ordaining monks, hitherto laymen, to fit them better for missionary work. But this led, not only to much more intercourse with the society of a lax and turbulent age than suited with claustral rules, but to ambition, as it became customary to fill several sees with monks from certain abbeys. The declension, notably in the habits of the superiors of wealthy houses, had become very marked, when a reformer arose in the person of a second Benedict, of Aniane in the modern department of the Hérault (750-821), who, in gratitude for an escape from drowning in the Ticino in 774, adopted the monastic life, and changed his name Witiza to that of the great Nursian monk. But he accounted the Benedictine rule too easy, and adopted instead the severest practices of Eastern monachism. He quitted the house of Seine, where he had been professed, and betook himself with a couple of companions to Aniane, where by 782 he had built a monastery for a thousand monks, with dependent cells, and collected a considerable library, paying special attention to the acquisition of the rules of the different monastic bodies both of East and West. He was transferred by his warm patron, the emperor Louis the Pious, to an abbey built for him near Aix-la-Chapelle, whence he acted as in some sense a superior-general and inspector of all the Benedictine houses, and drew up a harmony of all the rules he had collected to aid him in the task of reform. What he actually effected was the practical abolition of most of the competing codes, so as to leave the Benedictine in nearly sole possession, and to procure the enactment of a large body of canons in the council of Aix-la-Chapelle before mentioned, which laid down detailed provisions for the government of monasteries, whose very minuteness made them vexatious and ultimately intolerable, so that the reform lasted scarcely

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It was found that a new order was the best safety-valve for enthusiasm which might become dangerous if discouraged, but which could be made a valuable ally if allowed to take shape in a fresh society, hoping to surpass all its precursors; and it is worth remarking that the one occasion when this wise policy was departed from, when Peter Waldo vainly sought in 1179 recognition and sanction from Pope Alexander III. for his proposed institute of mission preachers, gave rise to a sect (the Waldenses) which is still existing, and which has given trouble to the Roman Church quite disproportionate to its numbers and influence. The Carmelites, founded by Berthold of Calabria on Mount Carmel about 1180, and incorporated under rule by Albert, Latin patriarch of Jerusalem in 1209, were the last order of importance which sprang up at this time; for the Gilbertines, an English order founded at Sempringham in Lincolnshire in 1148, curious chiefly for their double monasteries for men and women; the Beguines, *c.* 1170 (who are, however, notable for their semi-secular and parochial organization, whence many later active bodies have borrowed hints); the Humiliati, *c.* 1196; and the Trinitarians, for the ransom of captives amongst the Moors and Saracens, founded by John de Matha and Felix de Valois in 1197, never rose to great influence or popularity, though the Servites, an order of the year 1223, became powerful in Italy. This period of rapid multiplication was quickly followed by one of equally rapid decay, the first to show clear tokens of degeneracy being the once rigid Cistercians, who never recovered their old moral footing, and who, it may be mentioned, were accountable for much of that hatred of the Church of the Pale in Ireland

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a remarkable and widespread religious revival, a dead-lift to ministerial efficiency in every direction, repaid their early labours, while they had between them almost a monopoly of the popedom for nearly two hundred years. And one peculiarity of their organization gave them a degree of strength which no other orders possessed. Each monastery of the older societies was practically isolated and independent of all others, unless it were itself a dependent priory or cell belonging to a greater house. Some societies had, it is true, general chapters, but these were rare, and at best only effectual in establishing a certain uniformity of practice in all houses of the same rule. But the Friars, like the Templars and Hospitallers of an earlier day, and like the Jesuits of a later one, were enrolled in something of military fashion, under a superior-general, with wide powers, who directed and controlled their actions from one central point. Every group of neighbouring friaries was formed into a congregation, under a local head or provincial, and he was always in direct communication with the general, so that a common government united the whole body into a compact mass. But their very success was fatal to their character. The vow of poverty was the first part of their institute to break down. Even before they began to be counted amongst the richest orders of Christendom, there is indisputable evidence—that of Bonaventura, himself general of the Franciscans—that the mendicant system was working nothing but mischief. He tells us, writing while the order was still very young, and within fifty years of the founder's death, that it was even more entangled in money cares and business concerns than the endowed communities, precisely because there were no funds available to fall back on in emergencies; that the brethren, discouraged from work by mendicancy, were habitually idle; that they roamed about in disorderly fashion under pretext of questing; that they were such brazen and shameless beggars as to make a Franciscan as much dreaded by travellers as a highwayman; that they made undesirable acquaintances, thus giving rise to evil reports and scandal; that conventual offices had to be entrusted to untried, unspiritual, and incompetent brethren; that vast sums were lavished on costly buildings; and that the friars were greedy in the pursuit of burial fees and of legacies, so that they encroached upon the rights of the parochial clergy. If such were the mischiefs at work before the first zeal had begun to cool, it may readily be gathered how entire was the failure at a later time. Indeed, as regards the Franciscans, not only did they endeavour to evade the stringency of their institute even in their founder's lifetime, but the whole society was soon divided into two hostile camps, one of which desired to adhere closely to the original rule, while the other was content to fall in with the habits of the "possessioners," as they had been wont contemptuously to name the endowed orders. And what is very curious in this connexion is that the friars who were loyal to the principle of poverty broke away for the most part from the church, forming new sects, such as the Fratricelli, or attaching themselves to elder ones, like the Beghards and the Apostolici, which handed on in secret the Gnostic traditions of the third century, apparently stamped out in the crusade against the Albigenses, while those who openly disregarded the will of their founder remained steadfastly in the Latin church. No order, except the Benedictines, has had so many branches and reforms as the Franciscans; amongst which it will suffice to name the Capuchins, the Minims, the Observants, and the Recollects; while the Poor Clares, the nuns of the institute, have also divided into Clarissines and Urbanists. The institution of Tertiaries, seculars affiliated to the order as honorary members, while continuing to live in the world, and adopting a certain modified daily rule, was a powerful factor in the success and strength of the order, and was adopted, but with less conspicuous results, by the Dominicans. The rivalry of these two great bodies with each other, prolonged with much bitterness for centuries, and their disputes with the parochial clergy, whom they long displaced in general repute and influence, belong rather to general church history than to the annals of monachism, and may be passed by with this brief allusion; while it suffices to say that all the support they, and the other less important communities of the same kind, such as the Carmelite and Austin Friars, received from the popes, whose most effective allies they were in every country where their houses were found, was not able to avert their decline in general estimation; and there is no figure in later mediæval literature on which the vials of contempt and indignation are so freely poured as on the begging friar, and that, it must be said, deservedly.

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As the 13th century is the apogee of later monachism, so the decline begins steadily at the very outset of the 14th (which is also the date of ordination becoming the normal custom for choir-monks, instead of the exception, as formerly), continuing down to the crash of the Reformation.[1] The great schism of the West, the rise of the Wickliffites and Lollards in England, and of the body later known as Hussites in Bohemia, could not fail to act injuriously on the monastic orders; and, though the creation of fresh ones continued, none of those founded during this era were influential, and few durable. It will suffice to name some of the more prominent:—the Olivetans in 1313, who were rigid Benedictines; the nuns of Bridget of Sweden in 1363, who followed a rule compiled from those of Basil and Augustine; the Hieronymite monks in 1374; the Brethren of the Common Life, founded by Gerard Groot in 1376, who did much for education and in home mission work, but are chiefly famous now in virtue of one member of their society, Thomas a Kempis; the Hieronymite Hermits in 1373-1377; the Minims in 1435; the Barnabites, a preaching and educational order, in 1484; the Theatins (a body of Clerks Regular who aimed at little more than raising the tone of clerical life, made but slight pretension to austerity, and are, indeed, mainly noticeable as having suggested to Ignatius Loyola several points which he adopted in regulating the mode of life to be pursued by the members of his institute) in 1524; and the Capuchins in 1525.

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It was the institute of the Sisters of Charity, established by Vincent de Paul in 1634, on the lines of the ancient community of the Hospitaller Nuns of St Augustine, but with some remarkable modifications, not only in respect of the vows, which were only yearly and inward, but in the spirit of their discipline, as formulated in his own memorable words,—"Your convent must be the houses of the sick; your cell, the chamber of suffering; your chapel, the parish church; your cloister, the streets of the city, or the wards of the hospital; your rule, the general vow of obedience; your grille, the fear of God; your veil to shut out the world, holy modesty." The original scheme of Francis de Sales for the Nuns of the Visitation, founded in 1610, was almost identical; but the opposition was then far too strong, and he was forced to make them a cloistered community. Vincent's order of Mission Priests, more commonly known as Lazarists, was also a successful and useful institute, though not vying in the extent of its influence with the other, which, as has been implied, has powerfully affected the organization of many of the active communities which have since been formed. No religious body did more to enable French monachism to bear up against the general obloquy it encountered during the 16th, 17th, and early 18th centuries,—a temper on the part of the public due to more than one cause. In the first place, the wars of religion had done much to harden and coarsen the feelings on both sides, and rigid adherence to the extreme positions of Catholics or Huguenots, as the case might be, was set far above any gentler and higher ideas. Next, the monasteries of both sexes had all but universally fallen into the patronage of the crown (in virtue of the concordat of Bologna, between Pope Leo X. and Francis I.), and were jobbed away as apanages for a dissolute nobility, who squandered the revenues, and suffered discipline to become relaxed, often to the generation of serious scandals. This malversation operated in two ways. It made the monasteries hard and bad landlords, grasping closely all the feudal privileges and monopolies which they continued to enjoy, a proceeding which bore hard on the tenants and labourers, so that the monks shared to the full the unpopularity of the nobles (precisely as was the case in Germany, during the Peasants' War of 1525); and the evil repute of the convents—of whose real character we get at least one trustworthy glimpse in the account of the abbey of Maubuisson which Angélique Arnauld reformed—came home to all the Huguenots and their friends, because both before and after the legal continuance of the edict of Nantes they were used (according to a very early application of monastic houses not yet obsolete) as prisons, where Huguenot women and girls were shut up in order to bring about their conversion, forcibly if necessary, but somehow in any case. And there is evidence to show that the Huguenots resented this policy most bitterly, not only on polemical grounds, but because they were firmly persuaded that the morals of their wives, daughters, and sisters were in no less peril than their faith in such places. When to this sentiment is added the hostility of the Jansenists to the school of opinion which had persecuted them, razed their famous house of Port-Royal, and literally flung the bones of its deceased members to the dogs, it will be easy to judge how powerful were the forces mustering for the overthrow of monachism, and how little even such stern reforms as De Rancé's at La Trappe, which has always had a marked attraction for soldiers, could do towards abating the danger. Nor were there wanting public scandals and cases before the law-courts which helped to fan the rising flames of hatred.[1] Another cause which contributed much to the decay of discipline and of practical religion in monasteries of both sexes was the custom which prevailed throughout the 16th, 17th, and 18th centuries, of disposing of the younger members of poor but noble families in the cloister as a safe and reputable provision, without any regard to the vocation of those so dedicated, and merely because the sum which sufficed to secure permanent admission was much smaller than that necessary to purchase a commission or public office for a son, or to provide an adequate dowry for a daughter.[2] At the Revolution, the religious houses, amounting (without reckoning various minor colleges and dependent establishments) to 820 abbeys of men and 255 of women, with aggregate revenues of 95,000,000 livres, were suppressed by the laws of 13th February 1790 and 18th August 1792. In Germany the storm had broken somewhat earlier, if not quite so violently. The Thirty Years' War had wrought much mischief to not a few of the religious houses, without taking into account the great number which had been destroyed in the territories of the Protestant princes; and when the death of Maria Theresa in 1780 left her son Joseph II. free to act as he pleased, he dissolved the Mendicant orders, and suppressed, in despite of the personal remonstrances of Pius VI., the greater number of monasteries and convents in his dominions. In Italy, despite the multiplication of new institutes, the process of decay continued throughout the 17th century, and one most remarkable testimony to the fact appears in the report of the Venetian ambassadors at Rome in 1650 to their government of an interview they had with Pope Alexander VII.

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2 This worked much evil in France, but produced perhaps even greater mischief in Germany, where what were styled "Noble Abbeys" were *not* uncommon, entrance to which, save in the inferior capacity of lay-members, was barred against all who could not prove patrician descent and a certain number of armorial quarterings. A relic of this survives in a few secular *Stiftungen* (Protestant and Catholic) for noble canonesses in Germany; and the notion was at any rate as respectable as that which holds good in some communities even now, where women who can pay a certain sum at entrance are admitted as choir-sisters, while those who cannot do so must accept the humbler position of lay-sisters.

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[2] This worked much evil in France, but produced perhaps even greater mischief in Germany, where what were styled "Noble Abbeys" were not uncommon, entrance to which, save in the inferior capacity of lay-members, was barred against all who could not prove patrician descent and a certain number of armorial quarterings. A relic of this survives in a few secular *Stiftungen* (Protestant and Catholic) for noble canonesses in Germany; and the notion was at any rate as respectable as that which holds good in some communities even now, where women who can pay a certain sum at entrance are admitted as choir-sisters, while those who cannot do so must accept the humbler position of lay-sisters.

who house and tend aged invalids. As a broad general rule, nearly every post-Reformation institute is styled, not an "Order," but a "Congregation"; but the only distinction which can be drawn between these two names is that "order" is the wider, and may include several congregations within itself (as the Benedictine order, for example, includes the congregations of Cluny and of St Maur), while a "congregation" is a simple unit, complete in itself, and neither dependent on another institute nor possessed of dependent varieties of its own. Another distinction drawn between the elder and younger societies is that the former are said to make "solemn vows," the latter only "simple vows." The difference here is not in the matter of the vows, which are usually the same in all cases, nor even in the ceremonies attending their utterance, which may also be alike, but in the superior binding efficacy of the solemn vows in Roman canon law, which rules that they so bind the member to his society, and the society to each member, that neither can sever the connexion, so that only the pope can dissolve it, and that in rare and exceptional cases alone. And it may be added that the term "religious" is restricted in the Latin Church to communities whose institute has been formally approved by the Roman see, and whose vows are for life, and not merely renewable,—a principle which excludes the Sisters of Charity, for example, from the use of this title. By the laws of France, and of some other countries, life-vows are invalid and even prohibited, but when they make part of the original institute, such disapproval by the civil power is not held to reduce them to the canonical level of temporary vows.

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On the other hand, several Roman Catholic societies have attained considerable success in the United States and Canada, thus in some degree recovering for the principle they represent part at least of the ground lost in Europe; while in three religious communions outside the pale of the Latin obedience—the Evangelicals of Germany, the Reformed of France, and the Church of England—the organization of women for charitable and religious work on the lines of various old institutes has been actively carried out. The Deaconesses of Kaiserswerth, founded by Pastor Fliedner in 1836, derive part of their rule, and even of their dress, from the Dames de St Augustine, themselves lineal descendants of the first Hospitallers of the crusades, and have ramified into several countries; the Strasburg and Mühlhausen Deaconesses derive theirs partly from the Flemish Beguines and partly from some points in the Moravian organization, itself handed down from those seceding Franciscans to whom the *Unitas Fratrum* really owes its origin; while the various Anglican communities, of which there are several, have borrowed freely from different sources, according to the preference and knowledge of each founder. Some attempts at reviving the common life for men also have likewise been made, but none on any large scale; only one has as yet exhibited any signs of vitality, a preaching order at Cowley, near Oxford, which has obtained some footing in England, and has even been able to spread to America.

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Chronological Table of Monastic Foundations.

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fusion. In mercantile phraseology the value of money means the interest charged for the use of loanable capital. Thus, when the market rate of interest is high money is said to be dear, when it is low money is regarded as cheap. Whatever may be the force of the reasons in favour of this use, it is only mentioned here for the purpose of excluding it. For our present subject, "the value of a thing is what it will exchange for; the value of money is what money will exchange for, or its purchasing power. If prices are low, money will buy much of other things, and is of high value; if prices are high, it will buy little of other things, and is of low value. The value of money is inversely as general prices, falling as they rise and rising as they fall."[1] Now in the general theory of value it appears that the *proximate* condition which determines it is the equation between supply and demand; and this is clearly the case with reference to money. These terms, supply and demand, need, however, some elucidation. Let us consider what is meant by the supply of, and demand for, money. The supply of a commodity means the quantity of it which is offered for sale. But in what shape does the sale of money take place? By being offered for goods. "The supply of money, then, is the quantity of it which people are wanting to lay out;" or, to put the point more concisely, it is "all the money *in circulation* at the time." Again, to take the case of demand,—the demand for a commodity is the purchasing power offered for it.[2] Demand in the special case of money consists of all the goods offered for sale. There is, however, a peculiar feature in the case of money which arises from its position as the medium of exchange, viz., that money is, so to say, in a "constant state of supply and demand," since its principal service is to act as the means of purchasing commodities.[3] From this it follows that the factors which determine the value of money within a given time are: (1) the amount of money in circulation, and (2) the amount of goods to be sold. On closer examination it will, however, appear that there are other elements to be taken into account. In the first place, the quantity of money is not by itself the sole element on the supply side. In some instances a coin will not circulate more than two or three times in a year, while another coin may make hundreds of purchases. In determining the value of money these varying rates of circulation have to be considered, and by taking an average we may establish the existence of a fresh element to be estimated, namely, the average rapidity with which money does its work, or, to use Mill's expression, "the efficiency of money." On the side of demand, again, it is not the quantity of commodities that is the determining element, but the amount of sales, and the same article may, and generally does, pass through several hands before it reaches the consumer. From this it follows that (if the consideration of credit in its various forms be omitted) the value of money is inversely as its quantity multiplied by its efficiency, the amount of transactions being assumed to be constant. This formula requires, however, some further explanations before it can be accepted as a full expression of the truth on the subject. It must be noticed that it is not commodities only that are exchanged for money. Services of all kinds constitute a large portion of the demand, while the payment of interest on the various forms of obligation requires a large amount of the circulating medium. The potent influence of credit also must be dwelt on. This latter force is the main element to be considered in dealing with variations of prices; but so far as it is based on a deposit of metallic money it may be looked on as a means of increasing the efficiency of money, and therefore as coming within the formula given above. In its other aspects it lies outside the range of this article. Some interesting conclusions may be deduced from the results we have arrived at. One of these is that the "increased development of trade," or "expansion of commerce," *of itself* tends to lower not to raise prices; for, by increasing the work which money has to do while the amount remains the same, it raises its value.[4] Another consequence is that a large addition may be made to the money in a country without any effect being produced on prices. This is evident, since money only acts on prices by being brought into circulation; therefore, if the money which is added to the national stock is not used in this way, prices will remain unaffected.

We have now sufficiently considered the proximate conditions which determine the value of money; the next step is to inquire: What is the ultimate regulator of its value? The value of freely-produced commodities is—according to the ordinary theory of economists—determined by their "cost of production," or, where the article is produced at different costs, by the cost of production of the most costly portion. We have now to consider how far this theory applies to the special case of money. Gold and silver, the principal materials of money, are the products of mines, and are produced at different costs; therefore the cost of the part produced at greatest cost ought to determine their value. This theory is, however, true only under certain conditions—namely, that competition is perfectly free, and that there are accurate data for computing the cost of production, and even then it is true only "in the long run." Moreover, cost only operates on value by affecting supply. "The latent influence," says Mill,[5] "by which the values of things are made to conform in the long run to the cost of production is the variation that would otherwise take place in the supply of the commodity." From these considerations it follows that cost of production does not so influentially affect the value of money as some writers have supposed. In former periods it was a common proceeding on the part of the state to either restrict or stimulate coinage and mining for the precious metals. At all times the working of gold and silver mines has been rather a hazardous speculation than a legitimate business. "When any person undertakes to work a new mine in Peru," says Adam Smith,[6] "he is universally looked upon as a man destined to bankruptcy and ruin, and is upon that account shunned and avoided by everybody. Mining, it seems, is considered there in the same light as here, as a lottery, in which the prizes do not compensate the blanks;" and all subsequent experience confirms this view. With regard to the adjustment of supply to meet an altered cost of production, the difficulties are, if possible, still greater. The supply of money is so large compared with the annual production, that any change can operate but slowly on its value. The total stoppage of fresh supplies from the mines would not be felt for some years in the increased value; and an increased amount of production, though more rapid in its operation, takes some time to produce an effect. "Hence the effects of all changes in the conditions of production of the precious metals are at first, and continue to be for many years, questions of quantity only, with little reference to cost of production." On these grounds it is apparent that cost of production is not, for short periods, the controlling force which governs the value of money, and even for long

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4. *Metallic Forms of Money. Their Superiority over other Substances. Special Advantages of Silver and Gold.*—The use of metals as a form of money can be traced far back in the history of civilization, but, as it is not possible to ascertain the historical order of their respective adoptions for this purpose, we will take them in the order of their value, beginning with the lowest. Iron, judging from the statement of Aristotle, was extensively employed as currency. One remarkable instance of this which at once occurs to the mind is the Spartan money, which is clearly a survival of the older system that had died out among the other Greeks, though by modern writers it has been attributed to ascetic policy. In conjunction with copper, iron formed an early Chinese currency, and till recently it was a subsidiary coinage in Japan. Iron spikes are used in Central Africa, while Adam Smith notices the use of nails for money in Scotland.[6] Lead has also served as money, as it does at present in Burmah. Copper has been more widely employed than either of the previously-mentioned metals. Its use in China as a parallel standard with iron has just been mentioned. The early Hebrew coins were chiefly composed of it, while down to 269 B.C. the sole Roman coinage was an alloy of copper. Till a very recent period it formed the principal money of some poorer European states (as Sweden), and was the subsidiary coinage of the United Kingdom till the present bronze fractional currency was introduced. Tin was not so favourite a material for money as copper, but the early English coinages were composed of it, probably on account of the fertile tin mines of Cornwall, and in later times halfpence and farthings of tin have been struck. The next metal which comes into notice is silver, which up to the last few years was the principal form of money, and even still is able to dispute the field with its most formidable rival. It formed the main basis of Greek coins, and was introduced at Rome in 269 B.C. The mediæval money was principally composed of silver, and its position in recent times will have to be subsequently noticed more at length. Gold, which is the most valuable of the metals widely used for monetary purposes, has been steadily gaining ground with the growth of commerce. The earliest trace of its use in common with that of silver is to be found "in the pictures of the ancient Egyptians weighing in scales heaps of rings of gold and silver."[7] The only other metals used for money—platinum and nickel—may be easily disposed of. The former of these was coined for a short time by the Russian Government, and then given up as unsuitable. The latter is only used as an alloy.

The examination of the forms of currency, both metallic and non-metallic, in which we have been engaged leads to certain definite conclusions as to the course which the evolution of currency is pursuing. It appears (1) that the metals tend to supersede all other forms of money among progressive peoples, and (2) that certain metals tend to supersede the others. From this we are led to consider the qualities which are desirable in the material of money, and to conclude that the presence or absence of those qualities is the reason of the adoption or rejection of any given substance.

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is a matter requiring much care. The objects aimed at in imposing the stamp are (1) to prevent the coin being counterfeited, and (2) to prevent any of the metal being abstracted. The former of these objects can be best attained by making the device such as can be obtained only by powerful and expensive machinery. The most improved methods must be adopted, and the greatest pains taken to have the device perfectly executed. The latest improvement in the process of coining is the introduction of the knee-joint press. The latter difficulty is best obviated by using special care in marking the edges of the coins. Ancient coins were issued with unstamped edges which presented no impediment to clipping, but modern coins, at least those of any size, are protected by the edge being milled or by a legend being inscribed round it. The combination of milled edges with a raised legend would be a still more effectual means of protecting the coinage from interference.

Another matter of importance in the process of coining is the nature and proportion of alloy to be used. The necessity for some mixture arises from the fact that gold and silver are both naturally soft, and, to obviate this, copper has been mixed with them, so as to produce a harder substance. The Austrian ducat is the nearest approach to purity among the principal coins of Europe, being composed of seventy-one parts of pure gold to one of alloy. The English gold coins are eleven-twelfths pure gold, while the silver ones are thirty-seven-fortieths pure silver. The origin of the difference is purely historical. The general gold proportion is nine-tenths gold to one-tenth alloy, while in some coinages the proportion of silver to alloy is nearly five to one, the countries composing the Latin Union having adopted that proportion in order to reduce their smaller silver coins to tokens. Copper is the usual material for alloying, but the Melbourne mint used silver for some time. It is this silvery alloy that accounts for the yellow appearance of many Australian sovereigns. They, however, are rapidly disappearing, as it is profitable to melt them down. It has been mentioned above that the wear of small coins is greater than that of large ones, and it may be added here that the wear of coins in general is an important question in connexion with their legal circulation. The English sovereign is believed to remain above the least current weight for from fifteen to twenty years. For the technical processes of coining, &c., reference may be made to the article MINT.

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In close connexion with the right of coining comes the consideration as to the proper persons to bear the expense of the process. At first sight the answer seems plain enough. Coins are a manufactured article quite as much as plate, and are rendered more valuable by being assayed, weighed, and certified. It appears therefore quite proper that those who bring metal to be coined should bear the expense of the coinage, or, in other words, should give up a part of the metal to the mint, thus paying for the service rendered to them in the same manner as those sending letters pay the postal department for their transmission. This course has been usually adopted. England, however, has taken a different line. In order to encourage the coining of the precious metals, no charge was made at the mint beyond that involved in the necessary delay in the operation; and this is at present the case with gold. Though this arrangement was originally introduced in obedience to the prejudices of the mercantile system which regarded gold and silver as being peculiarly wealth, it may be defended on reasonable grounds: for (1) the expense of the mint is very small compared with the amount of coin turned out, and (2) the coins produced are used by the nation, and therefore their expense may quite fairly be defrayed from the national revenue. Again, as the profit on the silver coinage (owing to circumstances to be subsequently discussed) is large, that may be set off against the free coinage of gold. The charge levied on coining, if confined to the expenses incurred, is called *brassage*; if it is anything above that cost it is known as *seigniorage*, which latter term is also used to denote both kinds of charge. The effect of seigniorage (using the term in its more extended sense) on the value of coins is to lower them, in fact, as Tooke has put it, seigniorage is always a kind of debasement, unless accompanied with limitation.[5] If the same quantity of metal be in circulation there will be a greater number of coins, and therefore nominal prices will be higher. It is, however, possible that the increased prices may check the production of the precious metals, thus making the value of the metal higher than it would otherwise be. Whether this will happen or not depends on the actual conditions of production, and is incapable of being predicted. One advantage which undoubtedly results from a charge on coinage is that it checks the tendency to melt coin when exported, for where a seigniorage is imposed coins are more valuable than the uncoined metal by the amount of the seigniorage. It therefore becomes the interest of the holder not to melt down the coins, as in doing so he loses the extra value given by the coining. Another factor in the expense of currency is the loss which arises from the wear and tear which money undergoes, and the consequent cost of replacing the light or missing pieces. The last and largest item is the interest on the total amount of money in use. To take the case of England, the value of the metallic currency is estimated at about £130,000,000. The interest

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The history of French depreciations did not terminate, as that of the English ones did, with the close of the 16th century; under Louis XIV. the livre was only one half of what it had been under Henry IV. The final result was that in 1789 the livre had come to be only one seventy-eighth of its weight in the time of Charlemagne. At the Revolution it was converted into the *franc*, at the rate of 81 livres to 80 francs.[13] It is not, however, to be supposed that the changes in the French currency were always towards debasement. The terrible evils arising from the debased coinage led to a general outcry, which in some cases was so strong as to force the king of the time to reform the monetary standard, one striking instance occurred in the reign of Philip IV.,[14] whose dealings with the currency led to his receiving the epithet of "le faux monnoyeur."

Depreciations in other Countries.—The very brief notice of the depreciations in the originally uniform currencies of England and France which has just been given is sufficient to establish the general tendency, and throws light enough on the resulting consequences; a similar course was followed in the other countries of Europe, but the details are too unconnected to be conveniently presented. A few facts will suffice. Thus, the German *florin* "was originally a gold coin of the value of about 10 shillings of our present money; it is now become a silver coin of the value of

1 As to the various elements requisite for a proper estimate of mediæval prices, see Cibrario, *Della Economia Politica del Medio Evo*, l. iii. c. 8.

2 The Tower pound, which was three quarters of an oz. troy less than the troy pound, was used in England until the 18th of Henry VIII. (1527), when it was replaced by the troy weight. This should be always remembered in considering the precise amount of depreciation at any given time.

3 *Coins of the Realm*, ch. xiii.

4 *Hist. of Eng.*, vii. p. 2.

5 Macaulay's account of this recoinage, which is written in his typical manner, has made this episode of English monetary history very generally known.

6 Lord Liverpool, *Coins of the Realm*, p 47.

7 The third great English recoinage was that of the *gold* coin, which took place in 1773-1775. It is commonly known as the recoinage of 1774.

8 33 & 34 Vic. c. 10.

9 A survival of this older system is to be found in many charges on Irish lands, which are reduced to English money by deducting *one* thirteenth from the nominal amount.

10 Hallam, *Middle Ages*, i. p. 206

11 Stephen, *Lectures on French History*, i. p 459.

12 Tooke and Newmarch, *Hist. of Prices*, vol. vi. p. 374. The views there given are based on those of M. Levasseur, who had specially studied the question.

13 The silver franc was made to weigh exactly 5 grammes

14 Stephen, *Lect. on French Hist.*, i p. 482.

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Depreciations in other Countries.—The very brief notice of the depreciations in the originally uniform currencies of England and France which has just been given is sufficient to establish the general tendency, and throws light enough on the resulting consequences; a similar course was followed in the other countries of Europe, but the details are too unconnected to be conveniently presented. A few facts will suffice. Thus, the German *florin* "was originally a gold coin of the value of about 10 shillings of our present money; it is now become a silver coin of the value of

[1] As to the various elements requisite for a proper estimate of mediæval prices, see Cibrario, *Della Economia Politica del Medio Evo*, l. iii. c. 8.

[2] The Tower pound, which was three quarters of an oz. troy less than the troy pound, was used in England until the 18th of Henry VIII. (1527), when it was replaced by the troy weight. This should be always remembered in considering the precise amount of depreciation at any given time.

[3] *Coins of the Realm*, ch. xiii.

[4] *Hist. of Eng.*, vii. p. 2.

[5] Macaulay's account of this recoinage, which is written in his typical manner, has made this episode of English monetary history very generally known.

[6] Lord Liverpool, *Coins of the Realm*, p. 47.

[7] The third great English recoinage was that of the *gold* coin, which took place in 1773-1775. It is commonly known as the recoinage of 1774.

[8] 33 & 34 Vic. c. 10.

[9] A survival of this older system is to be found in many charges on Irish lands, which are reduced to English money by deducting one thirteenth from the nominal amount.

[10] Hallam, *Middle Ages*, i. p. 206

[11] Stephen, *Lectures on French History*, i. p. 459.

[12] Tooke and Newmarch, *Hist. of Prices*, vol. vi. p. 374. The views there given are based on those of M. Levasseur, who had specially studied the question.

[13] The silver franc was made to weigh exactly 5 grammes

[14] Stephen, *Lect. on French Hist.*, i. p. 482.

teract the loss by wear and exportation,[1] and accordingly regard the metallic supply as fixed in amount until the next change in the conditions of production, which was the result of the discovery of America. Though 1492 is the date of the first landing, yet for some time no important additions were made to the supply of money. The conquest of Mexico (1519) gave opportunities of working the silver mines of that country, while the first mines of Chili and Peru were almost simultaneously discovered, and in 1545 those of Potosi were laid open. From this latter date we may regard the American supply

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Period.	No. of Years.	Amount in Kilos.		Value in Millions of Francs.		Ratio of Value of Gold to Silver.
		Gold.	Silver.	Gold.	Silver.	
1493-1520	28	162,400	1,316,000	560	292	11·3
1521-1544	24	171,800	2,164,000	592	481	11·2
1545-1580	36	273,600	10,976,000	940	2,439	11·5
1581-1600	20	147,600	8,378,000	508	1,862	11·9
1601-1620	20	170,400	8,458,000	587	1,880	13·0
1621-1640	20	166,000	7,872,000	572	1,749	13·4
1641-1660	20	175,400	7,326,000	604	1,628	13·8
1661-1680	20	185,200	6,740,000	638	1,498	14·7
1681-1700	20	215,300	6,838,000	742	1,520	15·0
1701-1720	20	256,400	7,112,000	883	1,580	15·2
1721-1740	20	381,600	8,624,000	1,314	1,916	15·1
1741-1760	20	492,200	10,663,000	1,695	2,370	14·8
1761-1780	20	414,100	13,055,000	1,426	2,900	14·8
1781-1800	20	355,400	17,581,000	1,225	3,906	15·1
1801-1810	10	177,800	8,942,000	612	1,987	15·6
1811-1820	10	114,400	5,408,000	394	1,202	15·5
1821-1830	10	142,200	4,606,000	490	1,023	15·8
1831-1840	10	202,900	5,964,000	699	1,325	15·7
1841-1850	10	547,600	7,804,000	1,887	1,734	15·8
1851-1855	5	987,600	4,431,000	3,402	985	15·4
1856-1860	5	1,000,000	4,525,000	3,540	1,006	15·3
1861-1865	5	925,000	5,505,000	3,188	1,223	15·4
1866-1870	5	982,500	6,695,000	3,385	1,488	15·6
1871-1875	5	855,400	9,847,000	2,949	2,188	16·0
1876	1	171,700	2,755,000	591·5	525·5	17·8
1877	1	182,800	2,428,000	629·5	539·5	17·19
1878	1	183,700	2,603,000	632·6	578·3	17·96
1879	1	156,900	2,557,000	540·3	568·2	18·39
1876-1879	4	695,100	9,553,000	2,394	2,211	17·40
1493-1850	358	4,752,100	149,828,000	16,378	33,292	14·05
1851-1879	29	5,451,200	40,957,000	18,778	9,101	15·85
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as an influential factor in the matter,[2] and look upon the stock of money as increasing. The annual addition to the store of money has been estimated as £2,100,000 for the period from 1545 to 1600. At this date the Brazilian supply began. The course of distribution of these fresh masses of the precious metals is an interesting point, which has been studied by Mr Cliffe Leslie.[3] The flow of the new supplies was first towards Spain and Portugal, and from thence they passed to the larger commercial centres of the other European countries, the effect being that prices were raised in and about the chief towns, while the value of money in the country districts remained unaltered. The additions to the supply of both gold and silver during the two centuries 1600-1800 continued to be very considerable; but, if Adam Smith's view be correct, the full effect on prices was produced by 1640,[4] and the increased amount of money was from that time counterbalanced by the wider extension of trade.[5] At the commencement of this century, the annual production of gold has been estimated as being from £2,500,000 to £3,000,000. The year 1809 seems to mark an epoch in the production of these metals, since the outbreak of the revolts of the various Spanish dependencies in South America tended to check the usual supply from those countries, and a marked increase in the value of money was the consequence. During the period 1809-1849 the value of gold and silver rose to about two and a half times their former level, notwithstanding fresh discoveries in Asiatic Russia.[6] The annual yield in 1849 was estimated at £8,000,000. The next important date for our present purpose is the year 1848, when the Californian mines were opened, while in 1851 the Australian discoveries took place. By these events an enormous mass of gold was added to the world's supply. The most careful estimates fix the addition during the years 1851-1871 at £500,000,000, or an amount nearly equal to the former stock in existence. The problems raised by this phenomenon have received the most careful study by several distinguished economists,[7] to whose writings those desiring more extensive information may refer. The main features of interest may be briefly summed up. (1) The additional supply was almost entirely of *gold*, thus tending to produce a distinction between the two principal monetary metals and an alteration in the currency of bimetallic countries. Under this influence France, from being a silver-using, became a gold-using, country. (2) The contemporaneous development of the Continental railway systems, and the partial adoption of free trade, with the consequent facilities for freer circulation of commodities, led to the course of distribution being different from that of the 16th century. The more backward districts were the principal gainers, and a more general equalization of prices combined with a slight elevation in value was the outcome. (3) The increased supply of gold rendered a general currency reform possible, and made the use of a gold monometallic standard appear feasible. The movements for currency reform, as will be seen, all arose after these discoveries. (4) The change in the value of money, which may for the period 1849-1869 be fixed at 20 per cent., enabled a general increase of wages to be carried out, thus improving the condition of the classes living on manual labour. It may be added that the difficulty of tracing the effects of this great addition to the money stock is a most striking proof of the complexity of modern economic development. (5) The last point to be noticed is the very small influence exercised on the value of silver by the new gold.[8] Hardly had the gold discoveries of 1848-1851 ceased to produce a decided effect when new silver mines of unusual fertility came into working. During the period immediately succeeding the gold discoveries the production of silver remained at an annual amount of from £8,000,000 to £9,000,000. This amount suddenly, about 1870, increased to £15,000,000,[9] and remained at that amount for the next five years. More than half of the supply came from new mines opened in Nevada. This increased supply was accompanied by a marked depreciation in the gold price of silver, though the prices of commodities in countries having a silver standard did not rise. The result of the close investigations to which all aspects of the question were subjected was to show that the increased production of silver was only a minor element in causing its depreciation. The policy pursued by various states—viz., (1) Germany and the Scandinavian

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owing to the habits of the people not having been attended to. Some writers have, however, misconceived the principles of currency and extended this influence to cases where it does not apply. Thus it has been sought to explain the adoption of gold as the principal English coinage after 1696 by assuming that the English deliberately preferred that metal.[1] The fact of different nations possessing different currencies, as the prevalence of gold in England and of silver in France during the 18th century, is to be otherwise accounted for. The great mass of a population, it is true, take and give money without particularly observing it. It is enough if the coin conforms to the usual type. There exists, however, in all mercantile communities a class of dealers in money[2] who make a profit by selecting the best coins for exportation, or, if two metals are in concurrent use, the coins of that metal which is undervalued in the proportion fixed. The mode in which self-interest thus operates produces an effect which may be briefly formulated by saying that *bad money drives out good money*. It is often now called "Gresham's law," from a former master of the English mint,[3] who observed it. The illustrations of its working are numerous. Under its action the gold which was overvalued relatively to silver in England in 1696 became the main English coinage, as above stated. And in order to meet the want of silver coins, Sir I. Newton advocated, and secured, the reduction of the guinea from 21s. 6d. to 21s. The exportation of metallic money when an over-issue of inconvertible paper takes place is another case of the theorem. By means of this principle we can easily explain the tendency of currency to depreciation, for when once, either by wear or by the issue of inferior coins, a currency has become debased, no reformation is possible unless the debased coins are removed from circulation, as otherwise they will be preferred for payments by dealers, and will not be melted down or exported. All demands for foreign trade will be met from the best part of the coinage. An argument in favour of state coinage has been founded on Gresham's law. It is argued that private coinage would lead to the issue of depreciated money.[4] It is, however, overlooked in this argument that the action of the law arises from the fact that the depreciated currency is legal tender; were it not so, coins less than the proper weight would be at once rejected. It may be added that Greek monetary history bears out this view.[5]

Having disposed of these elementary questions, the general groups into which all currency systems fall may now be stated. The simplest form of currency seems to be that in which the state coins ingots of different metals, and allows them to circulate freely, without any ratio being fixed. This, which is the lowest form of currency proper,[6] has arisen in many countries through the introduction of coins of various other nations. Turkey is a European example. Many of the South American republics possess a currency of this description. A theoretical form of this system has been advocated in France. It is proposed to issue coins of one, two, five, and ten grammes of gold, and to allow the present silver coins which are multiples of the gramme to circulate along with them. The difficulties of this plan are so obvious that there is no likelihood of its being adopted. The arguments in its favour are of little force, since it is hardly correct to contend that it is a natural system, when it has never been willingly adopted by any country. The next system to be noticed is that of a single metal being fixed as legal tender. This in early times is the really natural arrangement, and has been widely adopted. It is needless to recapitulate the instances which have already been given in dealing with other matters. There is, however, a difficulty which soon arises under this system. If the metal chosen is not very valuable, it is too cumbrous for large payments; if, on the other hand, it possesses a high value, it is hard to coin pieces suitable for small transactions. Thus, even silver would be too bulky for such payments as frequently occur. £100 in silver at its present value would weigh nearly 40 lb, while it would be impossible to coin gold pieces of the value of a penny or even a shilling. This system thus naturally leads to the use of other metals besides the standard one, and when the state fixes the ratio between these metals a new system has come into existence, which has been called the *multiple tender* system. In it the ratios between the metals are fixed, either once for all, or until changed by state authority. This system was in force in England from 1257 (or rather 1344) to 1664, the ratio between gold and silver being fixed from time to time by proclamation. France, too, adopted it during the Revolution, the ratio of 15½ to 1 being that fixed between gold and silver. The fluctuation of currencies arranged on this method, owing to the action of Gresham's law, has led in England and Germany to a modified system, which seeks to combine any advantages of the multiple standard with the principle of the single standard. By this method one metal is fixed as the principal legal tender, while the smaller coins are made of a less valuable material, and circulated at a nominal value somewhat above their real one, or, in other words, as token coins, but they are only legal tender to a limited amount. This has been called the *composite legal tender* system.[7]

For further details reference may be made to Tables II. and III., and the notes appended. Every currency system requires the existence of subsidiary coins, and, as stated before, this want is met by using a less valuable metal, generally silver, and for smaller payments copper or bronze. But, apart from the question of the material of the smaller coins, it is important to determine the best ratio between them. The simplest of all would be the *binary*. In it each coin would be the half of the next highest one, and double the one immediately below it. Nothing, apparently, is plainer or simpler than this scale, but the objection to it is the great number of coins that would be required, as well as the want of conformity with the general arithmetical scale. In a modified form it does prevail in many countries. Thus in England we have the *penny, half-penny*, and *farthing*. At a higher stage we have the *florin, shilling, sixpenny piece*, and *threepenny piece*, and, again, the *sovereign, half-sovereign, five-shilling piece*,[8] and *half-crown*. The coinages of the Latin and Scandinavian Unions, as also those of Germany and the United States, have several binary series in their coins.[9] There is, however, no completely binary system known. The old English scale was partly *duodecimal*, and the arguments in favour of this arrangement are by no means weak. At present the shilling is duodecimally divided. It is urged in favour of this scale that the main divisions of time (year and month, day and hour, are duodecimally related, and that time is one of the elements in all questions of value.[10] Another argument is that 12 is capable of being resolved into several factors (2 and 6, 3 and 4), and therefore

[1] R. Giffen, *Essays in Finance*, p. 303.

[2] The Jewish and Lombard merchants discharged this function in the mediæval period; Hallam, *Middle Ages*, iii. p. 369, note *t*.

[3] Aristophanes (*Ran.* 719-733) appears to recognize this principle. Grote (vol. iii. 116 note) has misunderstood him, and seems to deny the principle stated.

[4] Jevons, *Money*, p. 82.

[5] See p. 726, above.

[6] In his discussion of this subject Prof. Jevons, on whose excellent work much of this section is based, mentions currency by weight as the simplest form, but it is hardly correct to regard this as a currency system; it is rather a primitive stage, closely akin to barter.

[7] This system came into existence in England accidentally, through silver being overvalued by the mint regulations, but its theoretical basis was given by the often-quoted work of Lord Liverpool, *Coins of the Realm* (1805), which contains even now the best explanation of its principles.

[8] This piece is now almost extinct.

[9] For instance, the 20-franc, 10-franc, and 5-franc pieces, and, again, 2-franc, 1-franc, and 50-centime pieces in France, &c.; 20-kroner and 10-kroner pieces, and 4-kroner, 2-kroner, 1-krone, 50-öre, and 25-öre pieces in Denmark, &c.; 20-, 10-, and 5-mark pieces, and 2-mark, 1-mark, and 50-pfennige pieces in Germany; while the United States have eagle, half-eagle, and quarter-eagle, and also dollar, half-dollar, and quarter-dollar.

[10] See S. Laing, *Notes of a Traveller*, pp. 57-59.

owing to the habits of the people not having been attended to. Some writers have, however, misconceived the principles of currency and extended this influence to cases where it does not apply. Thus it has been sought to explain the adoption of gold as the principal English coinage after 1696 by assuming that the English deliberately preferred that metal.[1] The fact of different nations possessing different currencies, as the prevalence of gold in England and of silver in France during the 18th century, is to be otherwise accounted for. The great mass of a population, it is true, take and give money without particularly observing it. It is enough if the coin conforms to the usual type. There exists, however, in all mercantile communities a class of dealers in money[2] who make a profit by selecting the best coins for exportation, or, if two metals are in concurrent use, the coins of that metal which is undervalued in the proportion fixed. The mode in which self-interest thus operates produces an effect which may be briefly formulated by saying that *bad money drives out good money.* It is often now called "Gresham's law," from a former master of the English mint,[3] who observed it. The illustrations of its working are numerous. Under its action the gold which was overvalued relatively to silver in England in 1696 became the main English coinage, as above stated. And in order to meet the want of silver coins, Sir I. Newton advocated, and secured, the reduction of the guinea from 21s. 6d. to 21s. The exportation of metallic money when an over-issue of inconvertible paper takes place is another case of the theorem. By means of this principle we can easily explain the tendency of currency to depreciation, for when once, either by wear or by the issue of inferior coins, a currency has become debased, no reformation is possible unless the debased coins are removed from circulation, as otherwise they will be preferred for payments by dealers, and will not be melted down or exported. All demands for foreign trade will be met from the best part of the coinage. An argument in favour of state coinage has been founded on Gresham's law. It is argued that private coinage would lead to the issue of depreciated money.[4] It is, however, overlooked in this argument that the action of the law arises from the fact that the depreciated currency is legal tender; were it not so, coins less than the proper weight would be at once rejected. It may be added that Greek monetary history bears out this view.[5]

Having disposed of these elementary questions, the general groups into which all currency systems fall may now be stated. The simplest form of currency seems to be that in which the state coins ingots of different metals, and allows them to circulate freely, without any ratio being fixed. This, which is the lowest form of currency proper,[6] has arisen in many countries through the introduction of coins of various other nations. Turkey is a European example. Many of the South American republics possess a currency of this description. A theoretical form of this system has been advocated in France. It is proposed to issue coins of one, two, five, and ten grammes of gold, and to allow the present silver coins which are multiples of the gramme to circulate along with them. The difficulties of this plan are so obvious that there is no likelihood of its being adopted. The arguments in its favour are of little force, since it is hardly correct to contend that it is a natural system, when it has never been willingly adopted by any country. The next system to be noticed is that of a single metal being fixed as legal tender. This in early times is the really natural arrangement, and has been widely adopted. It is needless to recapitulate the instances which have already been given in dealing with other matters. There is, however, a difficulty which soon arises under this system. If the metal chosen is not very valuable, it is too cumbrous for large payments; if, on the other hand, it possesses a high value, it is hard to coin pieces suitable for small transactions. Thus, even silver would be too bulky for such payments as frequently occur. £100 in silver at its present value would weigh nearly 40 lb, while it would be impossible to coin gold pieces of the value of a penny or even a shilling. This system thus naturally leads to the use of other metals besides the standard one, and when the state fixes the ratio between these metals a new system has come into existence, which has been called the *multiple tender* system. In it the ratios between the metals are fixed, either once for all, or until changed by state authority. This system was in force in England from 1257 (or rather 1344) to 1664, the ratio between gold and silver being fixed from time to time by proclamation. France, too, adopted it during the Revolution, the ratio of 15½ to 1 being that fixed between gold and silver. The fluctuation of currencies arranged on this method, owing to the action of Gresham's law, has led in England and Germany to a modified system, which seeks to combine any advantages of the multiple standard with the principle of the single standard. By this method one metal is fixed as the principal legal tender, while the smaller coins are made of a less valuable material, and circulated at a nominal value somewhat above their real one, or, in other words, as token coins, but they are only legal tender to a limited amount. This has been called the *composite legal tender* system.[7]

For further details reference may be made to Tables II. and III., and the notes appended. Every currency system requires the existence of subsidiary coins, and, as stated before, this want is met by using a less valuable metal, generally silver, and for smaller payments copper or bronze. But, apart from the question of the material of the smaller coins, it is important to determine the best ratio between them. The simplest of all would be the *binary.* In it each coin would be the half of the next highest one, and double the one immediately below it. Nothing, apparently, is plainer or simpler than this scale, but the objection to it is the great number of coins that would be required, as well as the want of conformity with the general arithmetical scale. In a modified form it does prevail in many countries. Thus in England we have the *penny, half-penny,* and *farthing.* At a higher stage we have the *florin, shilling, six-penny piece,* and *threepenny piece,* and, again, the *sovereign, half-sovereign, five-shilling piece,*[8] and *half-crown.* The coinages of the Latin and Scandinavian Unions, as also those of Germany and the United States, have several binary series in their coins.[9] There is, however, no completely binary system known. The old English scale was partly *duodecimal,* and the arguments in favour of this arrangement are by no means weak. At present the shilling is duodecimally divided. It is urged in favour of this scale that the main divisions of time (year and month, day and hour, are duodecimally related, and that time is one of the elements in all questions of value.[10] Another argument is that 12 is capable of being resolved into several factors (2 and 6, 3 and 4), and therefore

[1] R. Giffen, *Essays in Finance,* p. 303.

[2] The Jewish and Lombard merchants discharged this function in the mediæval period; Hallam, *Middle Ages,* iii. p. 369, note *t.*

[3] Aristophanes (*Ran.* 719-733) appears to recognize this principle. Grote (vol. iii. 116 note) has misunderstood him, and seems to deny the principle stated.

[4] Jevons, *Money,* p. 82.

[5] See p. 726, above.

[6] In his discussion of this subject Prof. Jevons, on whose excellent work much of this section is based, mentions currency by weight as the simplest form, but it is hardly correct to regard this as a currency system; it is rather a primitive stage, closely akin to barter.

[7] This system came into existence in England accidentally, through silver being overvalued by the mint regulations, but its theoretical basis was given by the often-quoted work of Lord Liverpool, *Coins of the Realm* (1805), which contains even now the best explanation of its principles.

[8] This piece is now almost extinct.

[9] For instance, the 20-franc, 10-franc, and 5-franc pieces, and, again, 2-franc, 1-franc, and 50-centime pieces in France, &c.; 20-kroner and 10-kroner pieces, and 4-kroner, 2-kroner, 1-krone, 50-öre, and 25-öre pieces in Denmark, &c.; 20-, 10-, and 5-mark pieces, and 2-mark, 1-mark, and 50-pfennige pieces in Germany; while the United States have eagle, half-eagle, and quarter-eagle, and also dollar, half-dollar, and quarter-dollar.

[10] See S. Laing, *Notes of a Traveller,* pp. 57-59.

termediate coins are introduced, *e.g.*, in France, 2-franc and 5-franc pieces. In fact, most modern currencies are a combination of the decimal and binary systems, England alone adhering to a modified duodecimal scale. A decimal coinage has for the last sixty years been proposed for England, and it is almost certain that if any one scheme could be pointed out as much preferable to any other it would be accepted. As it is, there are two or three proposals, each commanding some support, while many advocates of the decimal system prefer to wait till an international agreement for its adoption can be obtained. One of the schemes advanced takes the present *farthing* as its base; then 10 *farthings*=1 *doit* (2½d.); 10 *doits*=1 *florin* (2s. 1d.); 10 *florins*=1 *pound* (20s. 10d.). The advantages of this plan are: (1) that the smaller coins now in use could be preserved (the penny being 4 farthings), (2) retail prices, which are for the smaller articles estimated in pence, need not be altered, (3) nor need those which affect postage, tolls, and mileage charges. Against these may be set the loss of the unit of value, the pound, which should be raised to 20s. 10d., so that all accounts, and all large

TABLE III.—*Currencies of the more important non-European States.*

Coins		Material.	Weight in Grammes.	Millesimal Fineness.	Rem. p. 1000. In Fineness.	Rem. p. 1000. In Weight.	Approximate Money Value. English.	Approximate Money Value. United States.
A. NORTH AMERICA.							£ s. d.	$ c.
BRITISH DOMINIONS[1]— 100 *Cents*=1 *Dollar*.								
MEXICO[2]— 100 *Cents* =1 *Dollar*.	16 Dollar piece	Gold	27·067	875·	..	..	3 4 9	15 74
	8 "	"	13·533	875·	..	..	1 12 4½	7 87
	4 "	"	6·767	875·	..	..	0 16 2¼	3 93
	2 "	"	3·383	875·	..	..	0 8 1	1 96
	1 "	"	1·692	875·	..	..	0 4 0½	0 98
	1 "	Silver	27·067	900·	..	..	0 4 0½	0 98
	50 Cent piece ..	"	13·533	900·	..	..	0 2 0	0 49
	25 "	"	6·767	900·	..	..	0 1 0	0 24
UNITED STATES[3]— 100 *Cents* =1 *Dollar*.	20 Dollar piece (Double Eagle)	Gold	33·436	900·	2·	1·	4 2 6	..
	10 Dollar piece (Eagle)	"	16·718	900·	2·	2·	2 1 3	..
	5 Dollar piece	"	8·359	900·	2·	2·	1 0 7½	..
	3 "	"	5·015	900·	2·	2·	0 12 4½	..
	2½ "	"	4·179	900·	2·	3·	0 10 4	..
	1 "	"	1·671	900·	2·	3·	0 4 1½	..
	1 "	Silver	26·729	900·	3·	5·	0 4 1½	..
	50 Cent piece ..	"	12·500	900·	3·	5·	0 2 0½	..
	25 "	"	6·250	900·	3·	5·	0 1 0¼	..
	10 "	"	2·500	900·	3·	..	0 0 5	..
	5 "	"	1·250	900·	3·	..	0 0 2½	..
	3 "	"	0·802	750·	3·	..	0 0 1½	..
B. SOUTH AMERICA.								
ARGENTINE REPUBLIC*[4]— 100 *Centesimos* =1 *Dollar* (*Peso*).	20 Peso piece ..	Gold	33·333	900·	..	..	4 1 8	19 94
	10 "	"	16·666	900·	..	..	2 0 10	9 97
	5 "	"	8·333	900·	..	..	1 0 5	4 98
	1 "	Silver	27·11	900·	..	..	0 4 1	0 99
BRAZIL*[5]— 1000 *Reis* =1 *Milrei*.	20 Milreis piece	Gold	17·927	916·6	..	..	2 4 10½	10 91
	10 "	"	8·963	916·6	..	..	1 2 5	5 45
	2 "	Silver	25·500	916·6	..	..	0 4 5	1 9
	1 "	"	12·250	916·6	..	..	0 2 2½	0 55
	½ "	"	6·375	916·6	..	..	0 1 1	0 27
CHILI*[6]— 100 *Centavos* =1 *Peso*.	10 Peso piece (Condor)	Gold	15·253	900·	..	..	1 17 6	9 10
	5 Peso piece ..	"	7·626	900·	..	..	0 18 9	4 55
	2 " ..	"	3·051	900·	..	..	0 7 6	1 82
	1 " ..	Silver	25·00	900·	..	..	0 3 9	0 91
	50 Centavos piece	"	12·50	900·	..	..	0 1 10½	0 45
	20 "	"	5·00	900·	..	..	0 0 9	0 18
	10 "	"	2·50	900·	..	..	0 0 4½	0 9
	5 "	"	1·25	900·	..	..	0 0 2	0 4

Coins.		Material.	Weight in Grammes.	Millesimal Fineness.	Rem. p. 1000. In Fineness.	Rem. p. 1000. In Weight.	Approximate Money Value. English.	Approximate Money Value. United States.
STATES OF COLOMBIA[7]— 100 *Centavos* =1 *Peso*.	20 Peso piece ..	Gold	32·258	900·	..	..	£3 19 3½	$19 30
	10 " (Condor)	"	16·129	900·	..	..	1 19 8	9 65
	5 Peso piece ..	"	8·065	900·	..	..	0 19 10	4 82
	2 " ..	"	3·225	900·	..	..	0 7 11¼	1 93
	1 "	Silver	25·0	900·	..	..	0 3 11¾	0 96
	20 Centavos....	"	5·0	835·	..	..	0 0 9¾	0 19
	10 "	"	2·5	835·	..	..	0 0 5	0 10
	5 "	"	1·25	835·	..	..	0 0 2½	0 5
PERU*[8]— 100 *Centesimos* =1 *Sol*.	20 Sol piece....	Gold	32·258	900·	..	..	3 19 3½	19 30
	10 "	"	16·129	900·	..	..	1 19 8	9 65
	5 "	"	8·065	900·	..	..	0 19 10	4 82
	2 "	"	3·225	900·	..	..	0 7 11¼	1 93
	1 "	"	1·613	900·	..	..	0 3 11¾	0 96
	1 "	Silver	25·0	900·	..	..	0 3 11¾	0 96
	50 Centesimos..	"	12·5	900·	..	..	0 1 11¾	0 48
	20 " ..	"	5·0	900·	..	..	0 0 9½	0 19
	10 " ..	"	2·5	900·	..	..	0 0 4¾	0 10
	5 " ..	"	1·25	900·	..	..	0 0 2¼	0 5
VENEZUELA. See COLOMBIA.								
C. ASIA.								
INDIA (BRITISH)[9]— 3 *Pie*=1 *Pice*. 4 *Pice*=1 *Ana*. 16 *Anas*=1 *Rupee*.	30 Rupee piece (Double Mohur)	Gold	23·321	916·6	..	..	3 0 0	14 58
	15 Rupee piece (Mohur)	"	11·665	916·6	..	..	1 10 0	7 29
	10 Rupee piece	"	7·772	916·6	..	..	1 0 0	4 86
	5 "	"	3·886	916·6	..	..	0 10 0	2 43
	1 "	Silver	11·665	916·6	..	..	0 2 0	0 48
	½ "	"	5·832	916·6	..	..	0 1 0	0 24
	¼ "	"	2·916	916·6	..	..	0 0 6	0 12
	⅛ "	"	1·458	916·6	..	..	0 0 3	0 6
JAPAN*[10]— 100 *Sen*=1 *Yen*.	20 Yen piece ..	Gold	33·333	900·	..	..	4 2 0	19 94
	10 " ..	"	16·666	900·	..	..	2 1 0	9 97
	5 " ..	"	8·333	900·	..	..	1 0 6	4 98
	2 " ..	"	3·333	900·	..	..	0 8 2	1 99
	1 " ..	"	1·666	900·	..	..	0 4 1	0 99
	50 Sen piece ..	Silver	10·	800·	..	..	0 2 0½	0 50
	20 " ..	"	4·	800·	..	..	0 0 10	0 20
	10 " ..	"	2·	800·	..	..	0 0 5	0 10
	5 " ..	"	1·	800·	..	..	0 0 2½	0 5

* Inconvertible paper currency.

Remarks.—The currencies of such of the non-European States as were capable of being presented in tabular form have been given above, but a brief outline of the currencies of less-advanced countries where a settled coinage does not prevail may be here added. The systems of the various European colonies in America are, as a rule, similar to their mother-countries. Some of the English possessions acquired by conquest preserve their original currency. In Cayenne the pre-Revolution French money is retained. In Paraguay and Uruguay a much-depreciated paper currency circulates. The Central American states reckon in dollars. The Australian colonies have a currency identical with that of England; the same currency exists in South Africa. In Mauritius the Indian system has been recently introduced. The various Turkish vassal states possess peculiar coinages. In Egypt, the coins of various European nations form the chief money. The Asiatic currencies are generally composed of silver. Ceylon has the Indian rupees. The money of Java has since 1877 been assimilated to the latest form of the Dutch monetary system. In China the *cash* forms the unit, and is made of copper, iron, and tin; silver passes by weight—a *tael*, which varies from place to place, being the unit; while the silver *sycee* is the usual medium of exchange. The other Asiatic currencies do not require particular notice.

1 There is no currency issued in Canada; English and American coins circulate. The standard is gold (£1=$4·80). There were formerly different methods of counting, viz., English sterling, Halifax currency, and Canadian sterling, the respective ratios being 100 : 120 : 108.

2 The decimal coinage has existed in Mexico since 1867. The gold coins are practically commercial money, and command a premium.

3 The dollar was introduced in 1786 as the unit. In 1794 the ratio of gold to silver was fixed at 1 to 15. This valuation underrated gold, consequently silver became the standard. In 1834 the ratio was altered to 1 to 16, and it was again changed in 1837. In these changes gold was overrated, and silver was driven out of circulation. This led, in 1853, to the reduction of the metal in the silver coins, which therefore became a token-currency. The suspension of cash payments took place in 1861. In 1873 silver was demonetized, and gold became the standard. In 1878 the "Bland Bill" was passed, making the silver dollar a legal tender, but confining its coinage to the executive, and fixing the amount at from two to four million dollars per month. These silver dollars have not got into circulation. The United States coin a trade dollar of 420 grs. (27·212 grammes), to compete with the Mexican dollar. The old South American *onza* weighed 27 grammes, was 875· fine, and worth £3, 4s. 6d.

4 The Argentine Confederation professes to have a gold standard.

5 The Brazilian system is a depreciated form of the Portuguese.

6 Chili has nominally a double valuation at 1 to 16[illegible]. Gold coins are no longer struck.

7 The Colombian States have the Latin Union system, with a ratio of 1 to 15½.

8 When Peru returns to cash payments the system will be almost identical with that of Colombia.

9 British India has a single silver standard, as the gold coins are only commercial money. The price of the rupee varies; generally in recent years it has been about 1s. 8d. (=40 cents).

10 The old Japanese coinage consisted of gold cobangs and silver itzibus, with a ratio of 1 to 4. The system was recast in 1871, and the present decimal coinage adopted, the ratio being 1 to 16·17. The standard is now practically silver. In 1875 a trade dollar exactly similar to the American trade dollar was introduced.

termediate coins are introduced, *e.g.*, in France, 2-franc and 5-franc pieces. In fact, most modern currencies are a combination of the decimal and binary systems, England alone adhering to a modified duodecimal scale. A decimal coinage has for the last sixty years been proposed for England, and it is almost certain that if any one scheme could be pointed out as much preferable to any other it would be accepted. As it is, there are two or three proposals, each commanding some support, while many advocates of the decimal system prefer to wait till an international agreement for its adoption can be obtained. One of the schemes advanced takes the present *farthing* as its base; then 10 *farthings*=1 *doit* (2½d.); 10 *doits*=1 *florin* (2s. 1d.); 10 *florins*=1 *pound* (20s. 10d.). The advantages of this plan are: (1) that the smaller coins now in use could be preserved (the penny being 4 farthings), (2) retail prices, which are for the smaller articles estimated in pence, need not be altered, (3) nor need those which affect postage, tolls, and mileage charges. Against these may be set the loss of the unit of value, the pound, which should be raised to 20s. 10d., so that all accounts, and all large

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	½ ,,	,,	6·375	916·6	..	..	0 1 1	0 27
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	1 ,, ..	Silver	25·0	900·	..	..	0 3 11½	0 96
	20 Centavos....	,,	5·0	835·	..	..	0 0 9½	0 19
	10 ,, ...	,,	2·5	835·	..	..	0 0 5	0 10
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	50 Centesimos..	,,	12·5	900·	..	..	0 1 11½	0 48
	20 ,, ..	,,	5·0	900·	..	..	0 0 9½	0 19
	10 ,, ..	,,	2·5	900·	..	..	0 0 4¾	0 10
	5 ,, ..	,,	1·25	900·	..	..	0 0 2½	0 5
VENEZUELA. See COLOMBIA.								
C. ASIA.								
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	1 ,,	Silver	11·665	916·6	..	..	0 2 0	0 48
	½ ,,	,,	5·832	916·6	..	..	0 1 0	0 24
	¼ ,,	,,	2·916	916·6	..	..	0 0 6	0 12
	⅛ ,,	,,	1·458	916·6	..	..	0 0 3	0 6
JAPAN*[10]— 100 *Sen*=1 *Yen*.	20 Yen piece ..	Gold	33·333	900·	..	..	4 2 0	19 94
	10 ,, ..	,,	16·666	900·	..	..	2 1 0	9 97
	5 ,, ..	,,	8·333	900·	..	..	1 0 6	4 98
	2 ,, ..	,,	3·333	900·	..	..	0 8 2	1 99
	1 ,, ..	,,	1·666	900·	..	..	0 4 1	0 99
	50 Sen piece ..	Silver	10·	800·	..	..	0 2 0½	0 50
	20 ,, ..	,,	4·	800·	..	..	0 0 10	0 20
	10 ,, ..	,,	2·	800·	..	..	0 0 5	0 10
	5 ,, ..	,,	1·	800·	..	..	0 0 2½	0 5

* Inconvertible paper currency.

Remarks.—The currencies of such of the non-European States as were capable of being presented in tabular form have been given above, but a brief outline of the currencies of less-advanced countries where a settled coinage does not prevail may be here added. The systems of the various European colonies in America are, as a rule, similar to their mother-countries. Some of the English possessions acquired by conquest preserve their original currency. In Cayenne the pre-Revolution French money is retained. In Paraguay and Uruguay a much-depreciated paper currency circulates. The Central American states reckon in dollars. The Australian colonies have a currency identical with that of England; the same currency exists in South Africa. In Mauritius the Indian system has been recently introduced. The various Turkish vassal states possess peculiar coinages. In Egypt, the coins of various European nations form the chief money. The Asiatic currencies are generally composed of silver. Ceylon has the Indian rupees. The money of Java has since 1877 been assimilated to the latest form of the Dutch monetary system. In China the *cash* forms the unit, and is made of copper, iron, and tin; silver passes by weight—a *tael*, which varies from place to place, being the unit; while the silver *sycee* is the usual medium of exchange. The other Asiatic currencies do not require particular notice.

1 There is no currency issued in Canada; English and American coins circulate. The standard is gold (£1=$4·80). There were formerly different methods of counting, viz., English sterling, Halifax currency, and Canadian sterling, the respective ratios being 100:120:108.

2 The decimal coinage has existed in Mexico since 1867. The gold coins are practically commercial money, and command a premium.

3 The dollar was introduced in 1786 as the unit. In 1794 the ratio of gold to silver was fixed at 1 to 15. This valuation underrated gold, consequently silver became the standard. In 1834 the ratio was altered to 1 to 16, and it was again changed in 1837. In these changes gold was overrated, and silver was driven out of circulation. This led, in 1853, to the reduction of the metal in the silver coins, which therefore became a token-currency. The suspension of cash payments took place in 1861. In 1873 silver was demonetized, and gold became the standard. In 1878 the "Bland Bill" was passed, making the silver dollar a legal tender, but confining its coinage to the executive, and fixing the amount at from two to four million dollars per month. These silver dollars have not got into circulation. The United States coin a trade dollar of 420 grs. (27·212 grammes), to compete with the Mexican dollar. The old South American *onza* weighed 27 grammes, was 875· fine, and worth £3, 4s. 6d.

4 The Argentine Confederation professes to have a gold standard.

5 The Brazilian system is a depreciated form of the Portuguese.

6 Chili has nominally a double valuation at 1 to $16\frac{7}{81}$. Gold coins are no longer struck.

7 The Colombian States have the Latin Union system, with a ratio of 1 to 15½.

8 When Peru returns to cash payments the system will be almost identical with that of Colombia.

9 British India has a single silver standard, as the gold coins are only commercial money. The price of the rupee varies; generally in recent years it has been about 1s. 8d. (=40 cents).

10 The old Japanese coinage consisted of gold cobangs and silver itzibus, with a ratio of 1 to 4. The system was recast in 1871, and the present decimal coinage adopted, the ratio being 1 to 16·17. In 1875 a trade dollar exactly similar to the American trade dollar was introduced. The standard is now practically silver.

their special knowledge would be saved to ordinary traders. (3) The improvement of the currencies of backward states. Many countries still possess those mixed currencies which were once common all over Europe, and much confusion consequently arises. The commercial coins have been introduced for international circulation,[1] and a universal currency would perform their function more satisfactorily. (4) Greater facility in comparing price-lists, &c. This advantage, which is reserved for the last, has been regarded by competent judges as the greatest.[2] It has a practical and a theoretical interest: the former, since trade with foreign countries would be rendered easier and safer; the latter, since statistical inquiries would be very much facilitated. At present, it is quite impossible for an ordinary trader to understand a set of foreign price-lists, each perhaps expressed in terms of a different currency from the others,—a difficulty which is enhanced by the variations of gold and silver values, not to add the case of an inconvertible paper currency. The existence of a common monetary language would remove these difficulties, and the premium on gold could be allowed for in the case of depreciated paper. A much wider development of smaller trading transactions would become possible, and would add to the world's wealth. Nor would the greater ease of statistical inquiry be unimportant; the rates of wages in different countries, and the profits on different transactions, would be readily compared, and the movements of labour and capital to the most advantageous points rendered more rapid. Against these great gains can be set only a certain and a possible disadvantage—namely, the loss and trouble involved in change, which would, of course, for the time be considerable, but would soon be over, and the chance that some states might issue a depreciated currency, which would expel the other and better coins. In the case of a universal coinage this case would hardly arise, since there would be no field of employment for the purer coins, and they would consequently remain in circulation, but the whole currency would become depreciated. Proper mint regulations, however, would obviate this danger, and could surely be devised. It may be said that the principal hindrance to one coinage system for all civilized states is the as yet unsettled question of the standard to be employed. Till the debate on this problem is closed it is vain to expect monetary unification. The establishment of a universal system based on gold seemed quite feasible to the conference of 1867, but doubtful to that of 1878, while a double standard was the proposal discussed in 1881.

9. *Considerations on the Questions arising from the Conflict of Standards.*—In the preceding section the various possible monetary systems were set forth, but no discussion was entered into with respect to their comparative merits. Only three of these systems need be here examined, namely, the *single* standard system, the *multiple* standard system, and, lastly, the *composite* system. Nor even is there any need for examining the various possible single or multiple standards. The single silver standard is the only one of the former, as the double gold and silver standard is the only one of the latter, which need be taken into account. It is true, historical inquiry has shown that the problem of the proper proportion between two different metals when used together presented itself to the Chinese with regard to their iron and copper coinages; but the course of monetary evolution, as discussed in section 3, has resulted in the rejection of the less valuable metals and in confining the material of the principal coins to silver and gold. The use of silver as a principal coinage was, as we have seen, widely diffused. The Hellenic coins were composed of that metal, gold being afterwards introduced as a variable commercial money; and copper was brought in still later as a token currency. Though copper preceded silver as money in Rome, the latter, soon after its introduction, succeeded in displacing it, the ratio first fixed being 1 to 250. A regular gold coinage did not exist at Rome till the empire, but gold in bars passed, the legal ratio being 1 to 11·91. Still the questions connected with the use of a double standard do not seem to have arisen.[3] The various European monarchies had silver as their principal money (see p. 726 *sq.*, above), gold where it was used being, as in Greece, a commercial money. The advance of gold to a position parallel to silver was commenced in the 13th and continued in the 14th century, the method of regulating the mixed gold and silver currencies being by proclamation, which fixed the varying ratios from time to time. In England this course was followed from the first introduction of gold coins (1257) to 1663.[4] From 1663 to 1717 silver was the standard, and the gold coins passed at their market value. As the silver coins were very much debased, the gold guinea sometimes was deemed equivalent to 30s. After the recoinage of 1696 the guinea passed at 21s. 6d. At this ratio silver was underrated, and was accordingly exported to Continental Europe and to India. The loss of the silver coins aroused the public attention, and the matter was submitted to Sir I. Newton, whose answer was given in his *Third Representation*. He proposed to reduce the guinea from 21s. 6d. to 21s. as an experimental measure.[5] The proper reduction for the object in view would have been to 20s. 8d. The silver drain, therefore, continued, and England came to have a gold currency. An opposite arrangement gave France a silver coinage. The recent facts of French monetary history, as well as those of the United States, illustrate the same condition of affairs. The difficulty of constituting a double standard system on a secure basis is thus made clear, so far at least as regards a single country. For the continuance of the two metals in the currency depends on the market ratio and the legal ratio between gold and silver being the same. The slightest examination of the history of these metals will show how variable they have been. Without accepting the estimates which regard silver as being more valuable than gold,[6] the well-attested variations of the precious metals have been very considerable. Thus, Herodotus estimates the ratio as 1 to 13, Plato 1 to 12, Menander 1 to 10, and in Cæsar's time the ratio was 1 to 9.[7] Table I. contains the variations since the discovery of America. In the 14th century the value of gold rose remarkably, and the gradual movement has ever since been towards an appreciation of gold relatively to silver. Another point, previously noticed, is the tendency, as wealth increases, to adopt a more valuable form of currency. Greece, Rome, and England all afford illustrations of this movement. The experience of the evils of a mixed currency led the earlier writers on coinage in England to regard a single standard system as the best, and silver as the most suitable metal for the standard. Locke, Petty, and Harris all advocated this view. The earlier Italian writers proposed to combine gold and silver at a ratio of 1 to 12, which they conceived to be the actual proportion. The theory of a composite system was, as before mentioned, first given by Lord Liverpool.[8] This method

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value of those substances shall be. They argue from history that several metals have been successively demonetized, that different ratios have been fixed between metals circulating together, that inconvertible paper currencies have been kept in circulation by the will of the state.[1] The doctrine of cost of production as determining the value of money is also assailed by them. They hold that it is the quantity of money which governs its value,[2] and that cost of production has little or no influence in the matter. The next step in the bimetallic argument is to contend that their proposed ratio for gold to silver (1 to 15½) can be maintained by the legal regulations to that effect. The common objection to bimetallism is, that whichever metal was undervalued would be exported. They answer that the same ratio existing over all, or a great part of, the world, there would be no inducement to export either metal, and in support of their argument they appeal to the passage from Newton quoted above, and claim him as the inventor of modern bimetallism.[3] Thirdly, a greater stability as regards value is claimed for the two metals combined than for either singly, since the fluctuations are distributed over a wider field, and, the conditions of production of gold and silver being somewhat different, fluctuations in them tend to counterbalance each other. A fourth point consists in the greater facilities which would exist for trade, since the fluctuations of the exchanges which arise from the existence of gold and silver currencies, and the variations of relative value of these metals, would under a bimetallic system disappear. The fifth argument for bimetallism is the advantages which would result from the increased prices caused by the greater abundance of money, or at all events from the check to any fall in prices which might arise from a diminution in the production of gold. The final argument is that a universal currency is desirable, and that, a single gold currency being by general consent practically impossible, this advantageous reform can be realized in no other way than by adopting a plan which permits the concurrent circulation of two metals. Most of these positions are contested by the monometallists, and even where any concession is made the value of the advantage to be reaped is estimated at a much smaller amount. The contention that the value of money is largely influenced by state demand is met by the assertion that cost of production is the ultimate regulator of value, and that any artificial regulation would stimulate the production of the cheaper metal, and thus flood the world with it. The fixing of a ratio different from the market one is derided by them as absurd, and an extreme case is instanced for this purpose. Is it possible, they ask, to make the value of silver equal to that of gold? If not, how can it be possible to alter the market ratio in even the slightest degree? Is there not a great demand for the precious metals in the various trades? And would not the ratio of this demand be affected by the fixing of a new ratio? The argument of bimetallists that their system would produce greater stability in the value of money is met by the answer that there is no proof of this. It is quite possible that a single metal may be steadier in value than two combined, and the evidence of history shows that silver is more liable to depreciation than gold. The argument derived from the advantages to exchange transactions is to a slight extent admitted, but it is pointed out that the factors which affect the foreign exchanges are so numerous, and are so rapidly eliminated in the course of trade, that a radical currency change need not be adopted for this purpose. It is also shown that, even when most European countries were bimetallic, fluctuations in the exchange price of silver took place; and still more that, where it is the less valuable metal that is in course of depreciation, bimetallism can afford no aid. The assumed tendency of the bimetallic scheme to produce a higher scale of prices than would otherwise prevail is dwelt on by opponents as a proof of its inherently vicious character. The claim to benefit the world by adding to its stock of money places bimetallists in the same class with the advocates of inconvertible paper money, and shows the absence of reason in their views. Their position becomes the same as that of the Birmingham currency school. The proposition that the quantity of money is of no consequence since prices vary in proportion to it is cited as conclusive, and the contempt so frequently expressed for bimetallists is accounted for by their advocacy of this principle of the beneficial effects of an increased amount of money. To the contention that bimetallism is the necessary condition for a universal coinage system the answer is, that the idea of universal coinage is premature, and that the *gradual* introduction of the gold standard is desirable as preparing the way for a future universal coinage based on gold monometallism. On the practical question as to the actual introduction of the system, the monometallists deny the possibility of forming a universal bimetallic league which would not be liable to be broken up by war, or impaired by some of the states which composed it issuing inconvertible paper. On the other hand, the various international conventions for postal purposes, extradition, commercial arrangements, and other matters of interest, are considered by bimetallists as evidences of the feasibility of their plan.[4]

The above summary gives the main arguments on each side of the discussion as given by the advocates of the contending principles. A short consideration will show that the controversy may be suitably divided into three heads, viz.—(1) the possibility of constructing a universal bimetallic system which shall be in accordance with sound economic principle; (2), if the first question be answered in the affirmative, the comparative merits of this system as opposed to the present variety of systems, or a future universal gold-standard system; and (3) the expediency under present circumstances of nations in general, and England in particular, joining in the proposed convention. Each of these topics calls for some remark. (1) The possibility of a bimetallic system can hardly be denied. Under all the difficulties attending its existence in a single country, it was retained in practical working in France during the early part of the 18th century, and it is plain that a widely-extended league would afford a better field for its action. It is quite possible that national preferences for one metal or the other would be displayed, but this would be no hindrance, since the exchanges would be regulated by the legal rate, and prices would depend on the total quantity of both metals (the amount of gold being multiplied by the legal ratio, and added to the amount of silver).[5] The objection which denies the power of Governments to fix the relative values of gold and silver, and which is supported by the instance of the extreme case of silver being made equal in value to gold, may be set aside by the consideration that the use of the precious metals takes two forms—(*a*) their use as commodities, (*b*) their use as money. Since the state can influence the demand for these metals as money, and since therefore it can raise the value of either of them by this increased demand, it follows that, within assignable limits, it can fix the ratios between them, and that these limits are "the ratio which would subsist between their values if gold were demonetized, and that which would subsist if silver were demonetized."[6] The possibility of bimetallism, if all nations were agreed, is allowed by some monometallists (*e.g.*, Professor Jevons), and an unconscious argument to this effect was given by the proposal of Chevalier, at the time of the Australian gold discoveries, to adopt silver as the standard and demonetize gold, which is a clear recognition of the force of law in monetary questions. It is therefore reasonable to answer in the bimetallists' favour the question first raised. (2) The considerations to be taken into account under the second head are far more complex, and do not admit of accurate determination. The present currency systems of England and the Scandinavian Union are based on the composite system, and afford the greatest satisfaction to the inhabitants of those countries. The bimetallic system of the Latin Union has been suspended, the introduction of silver as the principal money not being desired by the various peoples concerned. Germany has lost considerably by the sales of depreciated silver, and, were a gold standard once firmly established, it is not likely that any wish for change would be manifested. With silver countries the case is different. They have to receive masses of depreciated silver and to give commodities in exchange, while their purchasing power is reduced owing to the greater relative value of gold to silver. It would therefore be clearly advantageous for silver-using countries that a system should be adopted which would raise the value of their money, and save them from the necessity of importing large quantities of silver to produce a proper adjustment. The ultimate consequences of the complete demonetization of silver as regards silver-using countries are not so clear. The supply of gold might suffice for all wants, and might furnish a better currency than the heavier silver. The preservation of two separate monometallic systems, of gold for the more advanced countries of Europe and the United States, of silver for Russia and India, would, when the superfluous stock of silver had passed to the East, present little difficulty after equilibrium was attained. The new ratio between silver and gold would become established, and silver prices in silver-using countries would be higher in proportion to the fall in the value of silver. It is therefore plain that a suitable adjustment would be reached under any variety of currency systems, and it may therefore be concluded that the comparative merits of the competing standards are not capable of

[1] See Dana Horton's paper on the *Position of Law in the Doctrine of Money*, presented to the monetary conference of 1881 (Appendix iv. C)

[2] On p. 721, above, the theory of money value has been stated, and the objections to the cost of production theory given. It is strange to find Jevons arguing (in common with Bagehot and Prof. Price) that the value of money ultimately depends on cost of production, when his examination of that doctrine in general is considered. Compare *Contemp. Rev.* (May 1881) with Jevons's *Theory of Pol. Econ.*, p. 201 *sq.*

[3] Modern bimetallists freely admit that two different bimetallic systems—*i.e.*, having different ratios—could not exist, for each would drain the other of one metal.

[4] The principal sources for the above summary, besides works before cited, are the pamphlets of Seyd, Cernuschi, and De Laveleye, on the bimetallist side, as well as the articles of the latter in the *Fort* and *Contemp. Reviews*. The monometallist arguments are given by Prof. Jevons (*Contemp*, May 1881), Mr R. Giffen (*Essays in Finance*, pp. 286-310), and Lord Sherbrooke (*Nineteenth Century*, April 1882) See also the Report of the Paris conference, 1881, and Mr T. H. Farrer, *The State in its Relation to Trade*, pp. 49-52.

[5] It is assumed that the other factors which influence the value of money (see p. 722, above) remain constant.

[6] Mr J. J. Murphy in *Dublin Statistical Journal*, vol. viii. p. 282. See also M. Walras, *Journal des Économistes*, May 1881, "Théorie Mathématique du bimétallisme."

value of those substances shall be. They argue from history that several metals have been successively demonetized, that different ratios have been fixed between metals circulating together, that inconvertible paper currencies have been kept in circulation by the will of the state.[1] The doctrine of cost of production as determining the value of money is also assailed by them. They hold that it is the quantity of money which governs its value,[2] and that cost of production has little or no influence in the matter. The next step in the bimetallic argument is to contend that their proposed ratio for gold to silver (1 to 15½) can be *maintained* by the legal regulations to that effect. The common objection to bimetallism is, that whichever metal was undervalued would be exported. They answer that the same ratio existing over all, or a great part of, the world, there would be no inducement to export either metal, and in support of their argument they appeal to the passage from Newton quoted above, and claim him as the inventor of modern bimetallism.[3] Thirdly, a greater stability as regards value is claimed for the two metals combined than for either singly, since the fluctuations are distributed over a wider field, and, the conditions of production of gold and silver being somewhat different, fluctuations in them tend to counterbalance each other. A fourth point consists in the greater facilities which would exist for trade, since the fluctuations of the exchanges which arise from the existence of gold and silver currencies, and the variations of relative value of these metals, would under a bimetallic system disappear. The fifth argument for bimetallism is the advantages which would result from the increased prices caused by the greater abundance of money, or at all events from the check to any fall in prices which might arise from a diminution in the production of gold. The final argument is that a universal currency is desirable, and that, a single gold currency being by general consent practically impossible, this advantageous reform can be realized in no other way than by adopting a plan which permits the concurrent circulation of two metals. Most of these positions are contested by the monometallists, and even where any concession is made the value of the advantage to be reaped is estimated at a much smaller amount. The contention that the value of money is largely influenced by state demand is met by the assertion that cost of production is the ultimate regulator of value, and that any artificial regulation would stimulate the production of the cheaper metal, and thus flood the world with it. The fixing of a ratio different from the market one is derided by them as absurd, and an extreme case is instanced for this purpose. Is it possible, they ask, to make the value of silver equal to that of gold? If not, how can it be possible to alter the market ratio in even the slightest degree? Is there not a great demand for the precious metals in the various trades? And would not the ratio of this demand be affected by the fixing of a new ratio? The argument of bimetallists that their system would produce greater stability in the value of money is met by the answer that there is no proof of this. It is quite possible that a single metal may be steadier in value than two combined, and the evidence of history shows that silver is more liable to depreciation than gold. The argument derived from the advantages to exchange transactions is to a slight extent admitted, but it is pointed out that the factors which affect the foreign exchanges are so numerous, and are so rapidly eliminated in the course of trade, that a radical currency change need not be adopted for this purpose. It is also shown that, even when most European countries were bimetallic, fluctuations in the exchange price of silver took place; and still more that, where it is the less valuable metal that is in course of depreciation, bimetallism can afford no aid. The assumed tendency of the bimetallic scheme to produce a higher scale of prices than would otherwise prevail is dwelt on by opponents as a proof of its inherently vicious character. The claim to benefit the world by adding to its stock of money places bimetallists in the same class with the advocates of inconvertible paper money, and shows the absence of reason in their views. Their position becomes the same as that of the Birmingham currency school. The proposition that the quantity of money is of no consequence since prices vary in proportion to it is cited as conclusive, and the contempt so frequently expressed for bimetallists is accounted for by their advocacy of this principle of the beneficial effects of an increased amount of money. To the contention that bimetallism is the necessary condition for a universal coinage system the answer is, that the idea of universal coinage is premature, and that the *gradual* introduction of the gold standard is desirable as preparing the way for a future universal coinage based on gold monometallism. On the practical question as to the actual introduction of the system, the monometallists deny the possibility of forming a universal bimetallic league which would not be liable to be broken up by war, or impaired by some of the states which composed it issuing inconvertible paper. On the other hand, the various international conventions for postal purposes, extradition, commercial arrangements, and other matters of interest, are considered by bimetallists as evidences of the feasibility of their plan.[4]

The above summary gives the main arguments on each side of the discussion as given by the advocates of the contending principles. A short consideration will show that the controversy may be suitably divided into three heads, viz.—(1) the possibility of constructing a universal bimetallic system which shall be in accordance with sound economic principle; (2), if the first question be answered in the affirmative, the comparative merits of this system as opposed to the present variety of systems, or a future universal gold-standard system; and (3) the expediency under present circumstances of nations in general, and England in particular, joining in the proposed convention. Each of these topics calls for some remark. (1) The possibility of a bimetallic system can hardly be denied. Under all the difficulties attending its existence in a single country, it was retained in practical working in France during the early part of the 18th century, and it is plain that a widely-extended league would afford a better field for its action. It is quite possible that national preferences for one metal or the other would be displayed, but this would be no hindrance, since the exchanges would be regulated by the legal rate, and prices would depend on the total quantity of both metals (the amount of gold being multiplied by the legal ratio, and added to the amount of silver).[5] The objection which denies the power of Governments to fix the relative values of gold and silver, and which is supported by the instance of the extreme case of silver being made equal in value to gold, may be set aside by the consideration that the use of the precious metals takes two forms—(*a*) their use as commodities, (*b*) their use as money. Since the state can influence the demand for these metals as money, and since therefore it can raise the value of either of them by this increased demand, it follows that, within assignable limits, it can fix the ratios between them, and that these limits are "the ratio which would subsist between their values if gold were demonetized, and that which would subsist if silver were demonetized."[6] The possibility of bimetallism, if all nations were agreed, is allowed by some monometallists (*e.g.*, Professor Jevons), and an unconscious argument to this effect was given by the proposal of Chevalier, at the time of the Australian gold discoveries, to adopt silver as the standard and demonetize gold, which is a clear recognition of the force of law in monetary questions. It is therefore reasonable to answer in the bimetallists' favour the question first raised. (2) The considerations to be taken into account under the second head are far more complex, and do not admit of accurate determination. The present currency systems of England and the Scandinavian Union are based on the composite system, and afford the greatest satisfaction to the inhabitants of those countries. The bimetallic system of the Latin Union has been suspended, the introduction of silver as the principal money not being desired by the various peoples concerned. Germany has lost considerably by the sales of depreciated silver, and, were a gold standard once firmly established, it is not likely that any wish for change would be manifested. With silver countries the case is different. They have to receive masses of depreciated silver and to give commodities in exchange, while their purchasing power is reduced owing to the greater relative value of gold to silver. It would therefore be clearly advantageous for silver-using countries that a system should be adopted which would raise the value of their money, and save them from the necessity of importing large quantities of silver to produce a proper adjustment. The ultimate consequences of the complete demonetization of silver as regards silver-using countries are not so clear. The supply of gold might suffice for all wants, and might furnish a better currency than the heavier silver. The preservation of two separate monometallic systems, of gold for the more advanced countries of Europe and the United States, of silver for Russia and India, would, when the superfluous stock of silver had passed to the East, present little difficulty after equilibrium was attained. The new ratio between silver and gold would become established, and silver prices in silver-using countries would be higher in proportion to the fall in the value of silver. It is therefore plain that a suitable adjustment would be reached under any variety of currency systems, and it may therefore be concluded that the comparative merits of the competing standards are not capable of

[1] See Dana Horton's paper on the *Position of Law in the Doctrine of Money*, presented to the monetary conference of 1881 (Appendix A. C).

[2] On p. 721, above, the theory of money value has been stated, and the objections to the cost of production theory given. It is strange to find Jevons arguing (in common with Bagehot and Prof. Price) that the value of money ultimately depends on cost of production, when his examination of that doctrine in general is considered. Compare *Contemp. Rev.* (May 1881) with Jevons's *Theory of Pol. Econ.*, p. 201 *sq.*

[3] Modern bimetallists freely admit that two different bimetallic systems—*i.e.*, having different ratios—could not exist, for each would drain the other of one metal.

[4] The principal sources for the above summary, besides works before cited, are the pamphlets of Seyd, Cernuschi, and De Laveleye, on the bimetallist side, as well as the articles of the latter in the *Fort.* and *Contemp. Reviews*. The monometallist arguments are given by Prof. Jevons (*Contemp.*, May 1881), Mr R. Giffen (*Essays in Finance*, pp. 286-310), and Lord Sherbrooke (*Nineteenth Century*, April 1882). See also the *Report* of the Paris conference, 1881, and Mr T. H. Farrer, *The State in its Relation to Trade*, pp. 49-52.

[5] It is assumed that the other factors which influence the value of money (see p. 722, above) remain constant.

[6] Mr J. J. Murphy in *Dublin Statistical Journal*, vol. viii. p. 282. See also M. Walras, *Journal des Économistes*, May 1881, "Théorie Mathématique du bimétallisme."

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advanced Mongol guards reached Amid (Diarbekr), whither Jelál al-dín had retreated, before that unfortunate sovereign had any idea of their approach. Accompanied by a few followers, Jelál al-dín fled to the Kurdish mountains, where he was basely murdered by a peasant. The primary object of the Mongol invasion was thus accomplished; but, with the instinct of their race, they made this conquest but a stepping-stone to another, and without a moment's delay pushed on still farther westward. Unchecked and almost unopposed, they overran the districts of Diarbekr, Mesopotamia, Erbíl, and Khelat, and then advanced upon Azerbijan. So great was the terror with which these fierce warriors inspired the people of the provinces they attacked that single Mongols are said to have slain the inhabitants of entire villages without a hand having been raised against them. In the following year (1236) they invaded Georgia and Great Armenia, committing frightful atrocities, sparing neither man nor woman, young nor old, with the exception of those whom they saved to minister to their wants or passions. Tiflis was among the cities captured by assault, and Kars was surrendered at their approach in the vain hope that submission would gain clemency from the victors. Meanwhile, in 1235, Ogdai, whose troops were as numerous as their thirst for conquest was devouring, despatched three armies in as many directions. One was directed against Corea, one against the Sung dynasty, which ruled over the provinces of China south of the Yang-tsze Keang, and the third was sent westward into eastern Europe. This last force was commanded by Batu, the son of Juchi, Ogdai's deceased eldest brother, who took with him the celebrated Sabutai Bahádur as his chief adviser. Bulgar, the capital city of the Bulgars, fell before the force under Sabutai, while Batu pushed on over the Volga. With irresistible vigour and astonishing speed the Mongols made their way through the forests of Penza and Tamboff, and appeared before the "beautiful city" of Riazan. For five days they discharged a ceaseless storm of shot from their balistas, and, having made a breach in the defences, carried the city by assault on the 21st of December 1237. "The prince, with his mother, wife, sons, the boyars, and the inhabitants, without regard to age or sex, were slaughtered with the savage cruelty of Mongol revenge; some were impaled, some shot at with arrows for sport, others were flayed or had nails or splinters of wood driven under their nails. Priests were roasted alive, and nuns and maidens ravished in the churches before their relatives. 'No eye remained open to weep for the dead.'" Moscow, at this time a place of little importance, next fell into the hands of the invaders, who then advanced against Vladimir. After having held out for several days against the Mongol attacks, the city at length succumbed, and the horrors of Riazan were repeated. The imperial family, with a vast crowd of fugitives, sought shelter in the cathedral, only to perish by the swords of the conquerors or by the flames which reduced it to ashes. If possible, a more dire fate overtook the inhabitants of Kozelsk, near Kaluga, where, in revenge for a partial defeat inflicted on a Mongol force, the followers of Batu held so terrible a "carnival of death" that the city was renamed by its captors Mobalig, "the city of woe." With the tide of victory thus strong in their favour the Mongols advanced against Kieff, "the mother of cities," and carried it by assault. The inevitable massacre followed, and the city was razed to the ground. While the scene of bloodshed was at its height a catastrophe occurred which at any other time would have been considered of supreme horror. Under the weight of a vast crowd of fugitives the flat roof of the metropolitan church fell in, burying all, young and old, in a vast hecatomb.

Victorious and always advancing, the Mongols, having desolated this portion of Russia, moved on in two divisions, one under Batu into Hungary, and the other under Baidar and Kaidu into Poland. Without a check, Batu marched to the neighbourhood of Pesth, where the whole force of the kingdom was arrayed to resist him. The Hungarian army was posted on the wide heath of Mohi, which is bounded by "the vine-clad hills of Tokay," the mountains of Lomnitz, and the woods of Diosgyor. To an army thus hemmed in on all sides defeat meant ruin, and Batu instantly recognized the dangerous position in which his enemies had placed themselves. To add to his chances of success he determined to deliver his attack by night, and while the careless Hungarians were sleeping he launched his battalions into their midst. Panic-stricken and helpless, they fled in all directions, followed by their merciless foes. Two archbishops, three bishops, and many of the nobility were among the slain, and the roads for two days' journey from the field of battle were strewn with corpses. The king, Béla IV., was saved by the fleetness of his horse, though closely pursued by a body of Mongols, who followed at his heels as far as the coast of the Adriatic, burning and destroying everything in their way. Meanwhile Batu captured Pesth, and on Christmas Day 1241, having crossed the Danube on the ice, took Gran by assault. While Batu had been thus triumphing, the force under Baidar and Kaidu had carried fire and sword into Poland. At their approach the inhabitants of Cracow deserted the city, after having given it over to the flames. Disappointed at the loss of their expected spoil, the Mongols advanced to Wahlstatt in the neighbourhood of Liegnitz, where the Polish army under Duke Henry II. of Silesia awaited their onslaught. With savage impetuosity, the troops of Baidar rushed to the attack, and completely defeated the Poles. As usual, no quarter was given. The massacre was frightful, and Duke Henry himself was amongst the slain. It was a Mongol habit to cut off an ear from each corpse of their slaughtered foes, and on this occasion it is said that they filled nine sacks with these ghastly trophies. Following the example of the inhabitants of Cracow, the people of Liegnitz left but the blackened walls of what had once been the town as a prey for the Mongols, who without delay pushed south-eastward into Moravia as far as the vicinity of Troppau. While laying waste the country in the neighbourhood of that town, they received the announcement of the death of Ogdai, and at the same time a summons for Batu to return eastwards into Mongolia.

While his lieutenants had been thus carrying his arms in all directions, Ogdai had been giving himself up to ignoble ease and licentiousness. Like many Mongols, he was much given to drink, and it was to a disease produced by this cause that he finally succumbed on the 11th of December 1241. He was succeeded by his son Kuyuk, who reigned only seven years. Little of his character is known, but it is noticeable that his two ministers to whom he left the entire conduct of affairs were Christians, as also were his doctors, and that a Christian chapel stood before his tent. This leaning towards Christianity, however, brought no peaceful tendencies with it. On the contrary, we hear of an advance against the sultan of Rúm (Asia Minor), and of an expedition into Syria, by which that country was made tributary to the Great Mongol empire, of a fresh campaign against Corea, and of another attack on the Sung dynasty of China. On the death of Kuyuk dissensions which had been for a long time smouldering between the houses of Ogdai and Jagatai broke out into open war, and after the short and disputed reigns of Kaidu and Chapai, grandsons of Ogdai, the lordship passed away from the house of Ogdai for ever.

On the 1st of July 1251 Mangu, the eldest son of Tulé, and nephew to Ogdai, was elected khakan. With

advanced Mongol guards reached Amid (Diarbekr), whither Jelál al-dín had retreated, before that unfortunate sovereign had any idea of their approach. Accompanied by a few followers, Jelál al-dín fled to the Kurdish mountains, where he was basely murdered by a peasant. The primary object of the Mongol invasion was thus accomplished; but, with the instinct of their race, they made this conquest but a stepping-stone to another, and without a moment's delay pushed on still farther westward. Unchecked and almost unopposed, they overran the districts of Diarbekr, Mesopotamia, Erbíl, and Khelat, and then advanced upon Azerbijan. So great was the terror with which these fierce warriors inspired the people of the provinces they attacked that single Mongols are said to have slain the inhabitants of entire villages without a hand having been raised against them. In the following year (1236) they invaded Georgia and Great Armenia, committing frightful atrocities, sparing neither man nor woman, young nor old, with the exception of those whom they saved to minister to their wants or passions. Tiflis was among the cities captured by assault, and Kars was surrendered at their approach in the vain hope that submission would gain clemency from the victors. Meanwhile, in 1235, Ogdai, whose troops were as numerous as their thirst for conquest was devouring, despatched three armies in as many directions. One was directed against Corea, one against the Sung dynasty, which ruled over the provinces of China south of the Yang-tsze Keang, and the third was sent westward into eastern Europe. This last force was commanded by Batu, the son of Juchi, Ogdai's deceased eldest brother, who took with him the celebrated Sabutai Bahádur as his chief adviser. Bulgar, the capital city of the Bulgars, fell before the force under Sabutai, while Batu pushed on over the Volga. With irresistible vigour and astonishing speed the Mongols made their way through the forests of Penza and Tamboff, and appeared before the "beautiful city" of Riazan. For five days they discharged a ceaseless storm of shot from their balistas, and, having made a breach in the defences, carried the city by assault on the 21st of December 1237. "The prince, with his mother, wife, sons, the boyars, and the inhabitants, without regard to age or sex, were slaughtered with the savage cruelty of Mongol revenge; some were impaled, some shot at with arrows for sport, others were flayed or had nails or splinters of wood driven under their nails. Priests were roasted alive, and nuns and maidens ravished in the churches before their relatives. 'No eye remained open to weep for the dead.'" Moscow, at this time a place of little importance, next fell into the hands of the invaders, who then advanced against Vladimir. After having held out for several days against the Mongol attacks, the city at length succumbed, and the horrors of Riazan were repeated. The imperial family, with a vast crowd of fugitives, sought shelter in the cathedral, only to perish by the swords of the conquerors or by the flames which reduced it to ashes. If possible, a more dire fate overtook the inhabitants of Kozelsk, near Kaluga, where, in revenge for a partial defeat inflicted on a Mongol force, the followers of Batu held so terrible a "carnival of death" that the city was renamed by its captors Mobalig, "the city of woe." With the tide of victory thus strong in their favour the Mongols advanced against Kieff, "the mother of cities," and carried it by assault. The inevitable massacre followed, and the city was razed to the ground. While the scene of bloodshed was at its height a catastrophe occurred which at any other time would have been considered of supreme horror. Under the weight of a vast crowd of fugitives the flat roof of the metropolitan church fell in, burying all, young and old, in a vast hecatomb.

Victorious and always advancing, the Mongols, having desolated this portion of Russia, moved on in two divisions, one under Batu into Hungary, and the other under Baidar and Kaidu into Poland. Without a check, Batu marched to the neighbourhood of Pesth, where the whole force of the kingdom was arrayed to resist him. The Hungarian army was posted on the wide heath of Mohi, which is bounded by "the vine-clad hills of Tokay," the mountains of Lomnitz, and the woods of Diosgyor. To an army thus hemmed in on all sides defeat meant ruin, and Batu instantly recognized the dangerous position in which his enemies had placed themselves. To add to his chances of success he determined to deliver his attack by night, and while the careless Hungarians were sleeping he launched his battalions into their midst. Panic-stricken and helpless, they fled in all directions, followed by their merciless foes. Two archbishops, three bishops, and many of the nobility were among the slain, and the roads for two days' journey from the field of battle were strewn with corpses. The king, Béla IV., was saved by the fleetness of his horse, though closely pursued by a body of Mongols, who followed at his heels as far as the coast of the Adriatic, burning and destroying everything in their way. Meanwhile Batu captured Pesth, and on Christmas Day 1241, having crossed the Danube on the ice, took Gran by assault. While Batu had been thus triumphing, the force under Baidar and Kaidu had carried fire and sword into Poland. At their approach the inhabitants of Cracow deserted the city, after having given it over to the flames. Disappointed at the loss of their expected spoil, the Mongols advanced to Wahlstatt in the neighbourhood of Liegnitz, where the Polish army under Duke Henry II. of Silesia awaited their onslaught. With savage impetuosity, the troops of Baidar rushed to the attack, and completely defeated the Poles. As usual, no quarter was given. The massacre was frightful, and Duke Henry himself was amongst the slain. It was a Mongol habit to cut off an ear from each corpse of their slaughtered foes, and on this occasion it is said that they filled nine sacks with these ghastly trophies. Following the example of the inhabitants of Cracow, the people of Liegnitz left but the blackened walls of what had once been the town as a prey for the Mongols, who without delay pushed south-eastward into Moravia as far as the vicinity of Troppau. While laying waste the country in the neighbourhood of that town, they received the announcement of the death of Ogdai, and at the same time a summons for Batu to return eastwards into Mongolia.

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system of state granaries, which had fallen into disorder. His court was visited by Friar Odoric, who gives a minute description of the palace and its inhabitants. Speaking of the palace this writer says—

"Its basement was raised about two paces from the ground, and within there were twenty-four columns of gold, and all the walls were hung with skins of red leather, said to be the finest in the world. In the midst of the palace was a great jar more than two paces in height, made of a certain precious stone called merdacas (jade); its price exceeded the value of four large towns. . . . Into this vessel drink was conducted by certain conduits from the court of the palace, and beside it were many golden goblets, from which those drank who listed. . . . When the khakan sat on his throne, the queen was on his left hand, and a step lower two others of his women, while at the bottom of the steps stood the other ladies of his family. All those who were married wore upon their heads the foot of a man as it were a cubit and a half in length, and at the top of the foot there were certain cranes' feathers, the whole foot being set with great pearls, so that if there were in the whole world any fine and large pearls they were to be found in the decoration of those ladies."

The following years were years of great natural and political convulsions. Devastating floods swept over China, carrying death and ruin to thousands of homes; earthquakes made desolate whole districts; and in more than one part of the empire the banners of revolt were unfurled. The khakans who now successively occupied the throne, instead of striving to stem the tide of discontent and disorder, gave themselves up to every kind of debauchery. As a natural consequence, the conduct of affairs fell entirely into the hands of their ministers, who but too often reflected the vices of their sovereigns. A comet which appeared in the reign of Toghon Timur Khan, and which was believed to be the precursor of fresh disasters to the reigning house, justified the prediction by being almost immediately followed by an earthquake, which overthrew the temple of the Imperial Ancestors, from the altars of which, as if to complete the misfortune, the silver tablets of the emperors were in the consequent confusion stolen. It was not long before the popular discontent found vent. In order to prevent the recurrence of the periodical inundations caused by the overflow of the Yellow river, the emperor ordered a levy of 70,000 men to excavate a new channel for its dangerous stream, and imposed a heavy tax to meet the necessary expenses. These oppressive edicts overstrained the patience of the people, and they broke into open rebellion. Under various leaders the rebels captured a number of cities in the provinces of Keang-nan and Honan, and took possession of Hang-chow, the capital of the Sung emperors. At the same time pirates ravaged the coasts and swept the imperial vessels off the sea. While these combined disorders were disturbing the country, the emperor, under the guidance of Tibetan Lamas, was being initiated into the sensual enjoyments peculiar to the warmer climates of Asia.

Toghon Timur Khan.

In 1355 a Buddhist priest named Choo Yuen-chang became so impressed with the misery of his countrymen that he threw off his vestments and enrolled himself in the rebel army. His military genius soon raised him to the position of a leader, and with extraordinary success he overcame with his rude levies the trained legions of the Mongol emperor. While unable to defeat or check the rebels in the central provinces Toghon Timur was also called upon to face a rebellion in Corea. Nor were his arms more fortunate in the north than in the south. An army which was sent to suppress the revolt was cut to pieces almost to a man. These events made a dream which the emperor dreamt about this time of easy interpretation. He saw in his sleep "a wild boar with iron tusks rush into the city and wound the people, who were driven hither and thither without finding shelter. Meanwhile the sun and the moon rushed together and perished." "This dream," said the diviner, "is a prophecy that the khakan will lose his empire." The fulfilment followed closely on the prophecy. By a subterfuge, the rebels, after having gained possession of most of the central provinces of the empire, captured Peking. But Toghon Timur by a hasty flight escaped from his enemies, and sought safety on the shores of the Dolonor in Mongolia. For a time the western provinces of China continued to hold out against the rebels, but with the flight of Toghon Timur the Mongol troops lost heart, and in 1368 the ex-Buddhist priest ascended the throne as the first sovereign of the Ming or "Bright" dynasty, under the title of Hung-woo.

Thus ended the sovereignty of the house of Jenghiz Khan in China, nor need we look far to find the cause of its fall. Brave and hardy the Mongols have always shown themselves to be; but the capacity for consolidating the fruits of victory, for establishing a settled form of government, and for gaining the allegiance of the conquered peoples, have invariably been wanting in them. For a time their prowess and the exceptional ability of some of the first emperors of their line held the people of China in a bondage which was only outwardly peaceful, and, when the hands which held the reins lost their nervous power, and the troops, enervated by the softer climate of China, lost much of their hardihood, the long pent-up hatred of a foreign yoke broke out and with gathering strength drove the invaders back to their Mongolian pasture-grounds.

Not content with having recovered China, the emperor Hung-woo sent an army of 400,000 men into Mongolia in pursuit of the forces which yet remained to the khakan. Even on their own ground the disheartened Mongols failed in their resistance to the Chinese, and at all points suffered disaster. Meanwhile Toghon Timur, who did not long survive his defeat, was succeeded in the khakanate by Biliktu Khan, who again in 1379 was followed by Ussakhal Khan. During the reign of this last prince the Chinese again invaded Mongolia, and inflicted a crushing defeat on the khan's forces in the neighbourhood of Lake Buyur. Besides the slain, 2994 officers and 77,000 soldiers are said to have been taken prisoners, and an immense booty to have been secured. This defeat was the final ruin of the eastern branch of the Mongols, who from this time surrendered the supremacy to the western division of the tribe. At first the Keraits or Torgod, as in the early days before Jenghiz Khan rose to power, exercised lordship over the eastern Mongols, but from these before long the supremacy passed to the Oirad, who for fifty years treated them as vassals. Notwithstanding their subjection, however, the Keraits still preserved the imperial line, and khakan after khakan assumed the nominal sovereignty of the tribe, while the real power rested with the descendants of Toghon, the Oirad chief, who had originally attached them to his sceptre. Gradually, however, the Mongol tribes broke away from all governing centres, and established scattered communities with as many chiefs over the whole of eastern Mongolia. The discredit of having finally disintegrated the tribe is generally attached to Lingdan Khan (1604-1634), of whom, in reference to his arrogant and brutal character, has been quoted the Mongolian proverb: "A raging khakan disturbs the state, and a raging saghan (elephant) overthrows his keepers."

At this time the Mongols, though scattered and in isolated bodies, had recovered somewhat from the shock of the disaster which they suffered at the hand of the first Ming sovereign of China. When first driven northwards, they betook themselves to the banks of the Kerulon, from whence they had originally started on their victorious career; but gradually, as the Chinese power became weaker among the frontier tribes, they again pushed southwards,

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ten oxen, a hundred sheep, and a hundred sacks of kumiss. These last, however, instead of being filled with skins of the liquor which Mongolians love so well, contained armed men, who, when the Tatar was feasted, rushed from their concealment and killed him. A grandson of Merghus was the celebrated Wang Khan, who was sometimes the ally and sometimes the enemy of Jenghiz Khan, and has also been identified as the Prester John of early Western writers. In war he was almost invariably unfortunate, and it was with no great difficulty, therefore, that his brother Ki Wang detached the greater part of the Kerait tribes from his banner, and founded the Torgod chieftainship, named probably from the country where they settled themselves. The unrest peculiar to the dwellers in the Mongolian desert disturbed the Torgod as much as their neighbours. Their history for several centuries consists of nothing but a succession of wars with the tribes on either side of them, and it was not until 1672, when Ayuka Khan opened relations with the Russians, that the country obtained an even temporarily settled existence. Its position, indeed, at this time made it necessary that Ayuka should ally himself either with the Russians or with his southern neighbours the Turks, though at the same time it was obvious that his alliance with the one would bring him into collision with the other. His northern neighbours, the Cossacks of the Yaik and the Bashkirs, both subject to Russia, had the not uncommon propensity for invading his borders and harassing his subjects. This gave rise to complaints of the czar's government and a disposition to open friendly relations with the Krim khan. A rupture with Russia followed, and Ayuka carried his arms as far as Kasan, burning and laying waste the villages and towns on his route and carrying off prisoners and spoils. Satisfied with this vengeance, he advanced no farther, but made a peace with the Russians, which was confirmed in 1722 at an audience which Peter the Great gave him at Astrakhan. On Ayuka's death shortly after this event, he was succeeded by his son Cheren Donduk, who received from the Dalai Lama a patent to the throne. But this spiritual support availed him little against the plots of his nephew Donduk Ombo, who so completely gained the suffrages of the people that Cheren Donduk fled before him to St Petersburg, where he died, leaving his nephew in possession. With consummate impartiality the Russians, when they found that Donduk Ombo had not only seized the throne but was governing the country with vigour and wisdom, formally invested him with the khanate. At his death he was succeeded by Donduk Taishi, who, we are told, went to Moscow to attend the coronation of the empress Elizabeth, and to swear fealty to the Russians. After a short reign he died, and his throne was occupied by his son Ubasha. The position of the Torgod at this time, hemmed in as they were between the Russians and Turks, was rapidly becoming unbearable, and the question of migrating "bag and baggage" was very generally mooted. In the war between his two powerful neighbours in 1769 and 1770, Ubasha gave valuable assistance to the Russians. His troops took part in the siege of Otchakoff, and gained a decided victory on the Kalans. Flushed with these successes, he was in no mood to listen patiently to the taunts of the governor of Astrakhan, who likened him to a "bear fastened to a chain," and he made up his mind to break away once and for all from a tutelage which was as galling as it was oppressive. He determined, therefore, to migrate eastward with his people, and on the 5th of January 1771 he began his march with 70,000 families. In vain the Russians attempted to recall the fugitives, who, in spite of infinite hardships, after a journey of eight months reached the province of Ili, where they were welcomed by the Chinese authorities. Food for a year's consumption was supplied to each family; and land, money, and cattle were freely distributed. How many lost their lives on the toilsome march it is impossible to say, but it is believed that 300,000 persons survived to receive the hospitality of the Chinese. This migration is interesting as illustrating the many displacements of tribes and peoples which have taken place on the continent of Asia at different periods of history. Such another migration occurred between four and five thousand years ago, when the Chinese crossed from western Asia into their present empire; such, again, was the movement which carried the Osmanli Turks from north-eastern Asia into Asia Minor, and eventually across the Bosphorus. By this desperate venture the Torgod escaped, it is true, the oppression of the Russians, but they fell into the hands of other masters, who, if not so exacting, were equally determined to be supreme. The Chinese, flattered by the compliment implied by the transference of allegiance, settled them on lands in the province of Ili, in the neighbourhood of the Altai Mountains, and to the west of the desert of Gobi. But the price they were made to pay for this liberality was absorption in the Chinese empire. Like the other Chinese-subdued Mongols, the Torgod were divided into banners, and from that time forth they lost their individuality.

The Torgod.

Among the Mongol chiefs who rose to fame during the rule of the Ming dynasty of China was Toghon, the Kalmuk khan, who, taking advantage of the state of confusion which reigned among the tribes of Mongolia, established for himself an empire in north-western Asia. Death carried him off in 1444, and his throne devolved upon his son Ye-seen, who was no degenerate offspring. Being without individual foes in Mongolia for the same reason that Narvaez had no enemies—namely, that he had killed them all—he turned his arms against China, which through all history has been the happy hunting-ground of the northern tribes, and had the unexampled good fortune to take prisoner the Chinese emperor Ching-tung. But victory did not always decide in his favour, and, after having suffered reverses at the hands of the Chinese, he deemed it wise to open negotiations for the restoration of his imperial prisoner. Thus, after a captivity of seven years, Ching-tung re-entered his capital in 1457, not altogether to the general satisfaction of his subjects. On the death of Ye-seen, shortly after this event, the Kalmuks lost much of their power in eastern Asia, but retained enough in other portions of their territory to annoy the Russians by raids within the Russian frontier, and by constant acts of pillage. In the 17th century their authority was partly restored by Galdan, a Lama, who succeeded by the usual combination of wile and violence to the throne of his brother Senghé. Having been partly educated at Lhasa, he was well versed in Asiatic politics, and, taking advantage of a quarrel between the Black and White Mountaineers of Kashgar, he overran Little Bokhara, and left a viceroy to rule over the province with his capital at Yarkand. At the same time he opened relations with China, and exchanged presents with the emperor. Having thus secured his powerful southern neighbour, as he thought, he turned his arms against the Khalkhas, whose chief ground of offence was their attachment to the cause of his brothers. But his restless ambition created alarm at Peking, and the emperor K'ang-he determined to protect the Khalkhas against their enemy. Great preparations were made for the campaign. The emperor, in person commanding one of the two forces, marched into Mongolia. After enduring incredible hardships during the march through the desert of Gobi the imperial army encountered the Kalmuks at Chao-modo. The engagement was fiercely contested, but ended in the complete victory of the Chinese, who pursued the Kalmuks for 10 miles, and completely dispersed their forces. Immense

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A rupture with Russia followed, and Ayuka carried his arms as far as Kasan, burning and laying waste the villages and towns on his route and carrying off prisoners and spoils. Satisfied with this vengeance, he advanced no farther, but made a peace with the Russians, which was confirmed in 1722 at an audience which Peter the Great gave him at Astrakhan. On Ayuka's death shortly after this event, he was succeeded by his son Cheren Donduk, who received from the Dalai Lama a patent to the throne. But this spiritual support availed him little against the plots of his nephew Donduk Ombo, who so completely gained the suffrages of the people that Cheren Donduk fled before him to St Petersburg, where he died, leaving his nephew in possession. With consummate impartiality the Russians, when they found that Donduk Ombo had not only seized the throne but was governing the country with vigour and wisdom, formally invested him with the khanate. At his death he was succeeded by Donduk Taishi, who, we are told, went to Moscow to attend the coronation of the empress Elizabeth, and to swear fealty to the Russians. After a short reign he died, and his throne was occupied by his son Ubasha. The position of the Torgod at this time, hemmed in as they were between the Russians and Turks, was rapidly becoming unbearable, and the question of migrating "bag and baggage" was very generally mooted. In the war between his two powerful neighbours in 1769 and 1770, Ubasha gave valuable assistance to the Russians. His troops took part in the siege of Otchakoff, and gained a decided victory on the Kalans. Flushed with these successes, he was in no mood to listen patiently to the taunts of the governor of Astrakhan, who likened him to a "bear fastened to a chain," and he made up his mind to break away once and for all from a tutelage which was as galling as it was oppressive. He determined, therefore, to migrate eastward with his people, and on the 5th of January 1771 he began his march with 70,000 families. In vain the Russians attempted to recall the fugitives, who, in spite of infinite hardships, after a journey of eight months reached the province of Ili, where they were welcomed by the Chinese authorities. Food for a year's consumption was supplied to each family; and land, money, and cattle were freely distributed. How many lost their lives on the toilsome march it is impossible to say, but it is believed that 300,000 persons survived to receive the hospitality of the Chinese. This migration is interesting as illustrating the many displacements of tribes and peoples which have taken place on the continent of Asia at different periods of history. Such another migration occurred between four and five thousand years ago, when the Chinese crossed from western Asia into their present empire; such, again, was the movement which carried the Osmanli Turks from north-eastern Asia into Asia Minor, and eventually across the Bosphorus. By this desperate venture the Torgod escaped, it is true, the oppression of the Russians, but they fell into the hands of other masters, who, if not so exacting, were equally determined to be supreme. The Chinese, flattered by the compliment implied by the transference of allegiance, settled them on lands in the province of Ili, in the neighbourhood of the Altai Mountains, and to the west of the desert of Gobi. But the price they were made to pay for this liberality was absorption in the Chinese empire. Like the other Chinese-subdued Mongols, the Torgod were divided into banners, and from that time forth they lost their individuality.

The Torgod.

Among the Mongol chiefs who rose to fame during the rule of the Ming dynasty of China was Toghon, the Kalmuk khan, who, taking advantage of the state of confusion which reigned among the tribes of Mongolia, established for himself an empire in north-western Asia. Death carried him off in 1444, and his throne devolved upon his son Ye-seen, who was no degenerate offspring. Being without individual foes in Mongolia for the same reason that Narvaez had no enemies—namely, that he had killed them all—he turned his arms against China, which through all history has been the happy hunting-ground of the northern tribes, and had the unexampled good fortune to take prisoner the Chinese emperor Ching-tung. But victory did not always decide in his favour, and, after having suffered reverses at the hands of the Chinese, he deemed it wise to open negotiations for the restoration of his imperial prisoner. Thus, after a captivity of seven years, Ching-tung re-entered his capital in 1457, not altogether to the general satisfaction of his subjects. On the death of Ye-seen, shortly after this event, the Kalmuks lost much of their power in eastern Asia, but retained enough in other portions of their territory to annoy the Russians by raids within the Russian frontier, and by constant acts of pillage. In the 17th century their authority was partly restored by Galdan, a Lama, who succeeded by the usual combination of wile and violence to the throne of his brother Senghé. Having been partly educated at Lhasa, he was well versed in Asiatic politics, and, taking advantage of a quarrel between the Black and White Mountaineers of Kashgar, he overran Little Bokhara, and left a viceroy to rule over the province with his capital at Yarkand. At the same time he opened relations with China, and exchanged presents with the emperor. Having thus secured his powerful southern neighbour, as he thought, he turned his arms against the Khalkhas, whose chief ground of offence was their attachment to the cause of his brothers. But his restless ambition created alarm at Peking, and the emperor K'ang-he determined to protect the Khalkhas against their enemy. Great preparations were made for the campaign. The emperor, in person commanding one of the two forces, marched into Mongolia. After enduring incredible hardships during the march through the desert of Gobi the imperial army encountered the Kalmuks at Chao-modo. The engagement was fiercely contested, but ended in the complete victory of the Chinese, who pursued the Kalmuks for 10 miles, and completely dispersed their forces. Immense

ruler of Egypt, that he sent to demand in marriage a princess of the house of Jenghiz Khan. At first his request was refused by the proud Mongols, but the present of a million gold dinars, besides a number of horses and suits of armour, changed the refusal into an acquiescence, and in October 1319 the princess landed at Alexandria in regal state. Her reception at Cairo was accompanied with feasting and rejoicing, and the members of her escort were sent back laden with presents. With that religious toleration common to his race, Uzbeg Khan, having married one princess to Násir, gave another in marriage to George the prince of Moscow, whose cause he espoused in a quarrel existing between that prince and his uncle, the grand-prince Michael. Assuming the attitude of a judge in the dispute, Uzbeg Khan summoned Michael to appear before him, and, having given his decision against him, ordered his execution. The sentence was carried out with aggravated cruelty in sight of his nephew and accuser. From this time Uzbeg's sympathies turned towards Christianity. He protected the Russian churches within his frontiers, and put his seal to his new religious views by marrying a daughter of the Greek emperor, Andronicus III. He died in 1340, after a reign of twenty-eight years. His coins were struck at Sarai, Kharezm, Mokshi, Bulgar, Azak, and Krim, and are dated from 1313 to 1340. His son and successor, Tinibeg Khan, after a reign of only a few months, was murdered by his brother Janibeg Khan, who usurped his throne, and, according to the historian Ibn Haidar, proved himself to be "just, God-fearing, and the patron of the meritorious." These excellent qualities did not, however, prevent his making a raid into Poland, which was conducted in the usual Mongol manner, nor did they save his countrymen from being decimated by the black plague, which for the first time in 1345 swept over Asia and Europe, from the confines of China to Paris and London. With all their love of war the Mongols had a keen eye to monetary advantage, and Janibeg, who was no exception to the rule, concluded treaties with the merchant-princes of Venice and Genoa, in which the minute acquaintance displayed with shipping dues and customs charges shows how great were the advances the Mongols had made in their knowledge of European commerce since the days of Jenghiz Khan. The throne Janibeg had seized by violence was, in 1357, snatched from him by violence. As he lay ill on his return from a successful expedition against Persia he was murdered by his son Berdibeg, who in his turn was, after a short reign, murdered by *his* son Kulpa. With the death of Berdibeg the fortunes of the Golden Horde began rapidly to decline. As the Uzbeg proverb says,—"The hump of the camel was cut off in the person of Berdibeg."

The White Horde, or Eastern Kipchak.

But while the power of the Golden Horde was dwindling away, the White Horde or Eastern Kipchak, which was the inheritance of the elder branch of the family of Juchi, remained prosperous and full of vitality. The descendants of Orda, Batu's elder brother, being far removed from the dangerous influences of European courts, maintained much of the simplicity and vigour of their nomad ancestors, and the throne descended from father to son with undiminished authority until the reign of Urus Khan (1360), when complications arose which changed the fortunes of the tribe. Like many other opponents of the Mongol rulers, Khan Tuli Khoja paid with his life for his temerity in opposing the political schemes of his connexion Urus Khan. Toktamish, the son of the murdered man, fled at the news of his father's death and sought refuge at the court of the famous Timur-i-leng (Tamerlane), who received him with honour and at once agreed to espouse his cause. With this intention he despatched a force against Urus Khan, and gained some advantage over him, but, while fitting out another army to make a fresh attack, news reached him of the death of Urus. Only at Sighnak are coins known to have been struck during the reign of Urus, and these bear date from 1372 to 1375.

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of six hours destroyed all the churches, palaces, and houses, with the exception of the Kremlin, within a compass of 30 miles. Thousands of the inhabitants perished in the flames. "The river and ditches about Moscow," says Horsey, "were stopped and filled with the multitudes of people, laden with gold, silver, jewels, chains, ear-rings, and treasures. So many thousands were there burned and drowned that the river could not be cleaned for twelve months afterwards." Satisfied with the destruction he had indirectly caused, and unwilling to attack the Kremlin, the khan withdrew to the Crimea, ravaging the country as he went. Another invasion of Russia, a few years later (1572), was not so fortunate for the Mongols, who suffered a severe defeat near Molody, 50 versts from Moscow. A campaign against Persia made a diversion in the wars which were constantly waged between the Krim khan and the Russians, Cossacks, and Poles. So hardly were these last pressed by their pertinacious enemies in 1649 that they bound themselves by treaty to pay an annual subsidy to the khan. But the fortunes of war were not always on the side of the Tatars, and with the advent of Peter the Great to the Russian throne the power of the Krim Mongols began to decline. In 1696 the czar, supported by a large Cossack force under Mazeppa, took the field against Selim Girai Khan, and gained such successes that the latter was compelled to cede Azoff to him. By a turn of the wheel of fortune the khan had the satisfaction in 1710 of having it restored to him by treaty; but this was the last real success that attended the Tatar arms. In 1735 the Russians in their turn invaded the Crimea, captured the celebrated lines of Perekop, and ravaged Baghchi Serai, the capital. The inevitable fate which was hanging over the Krim Tatars was now being rapidly accomplished. In 1783 the Krim, together with the eastern portion of the land of the Nogais, became absorbed into the Russian province of Taurida.

Another branch of the Mongol family which requires mention is that of the Kazaks (see KIRGHIZ, vol. xiv. pp. 95, 96), whose ancient capital was Sighnak, which, as we have seen, passed into the hands of the great Timur. It will now only be necessary to refer briefly to the Uzbegs, who, on the destruction of the Golden Horde, assumed an important position on the east of the Caspian Sea. The founder of their greatness was the khan Abulkhair, who reigned in the 15th century, and who, like another Jenghiz Khan, consolidated a power out of a number of small clans, and added lustre to it by his successful wars. Sheibani Khan, his grandson, proved himself a worthy successor, and a doughty antagonist of the great Moghul emperor Baber. In 1500 he inflicted a severe defeat on Baber's forces, and captured Samarkand, Herat, and Kandahar. By these and other conquests he became possessed of all the country between the Oxus and the Jaxartes, of Ferghana, Kharezm, and Hissar, as well as of the territory of Tashkend from Kashgar to the frontiers of China. In the following year, by a dashing exploit, Baber recovered Samarkand, but only to lose it again a few months later. During several succeeding years Sheibani's arms proved victorious in many fields of battle, and but for an indiscreet outrage on the territories of the shah of Persia he might have left behind him a powerful empire. The anger, however, of Shah Ismael roused against him a force before which he was destined to fall. The two armies met in the neighbourhood of Merv, where, after a desperate encounter, the Uzbegs were completely defeated. Sheibani, with a few followers, sought refuge in a cattle-pound. But, finding no exit on the farther side, the refugees tried to leap their horses over the wall. In this attempt Sheibani was killed. When his body was recognized by his exultant enemies they cut off the head and presented it to the shah, who caused the skull to be mounted in gold and to be converted into a drinking-cup. After this defeat the Uzbegs withdrew across the Oxus and abandoned Khorásán. Farther east the news aroused Baber to renewed activity, and before long he reoccupied Samarkand and the province "Beyond the River," which had been dominated by the Uzbegs for nine years. But though the Uzbegs were defeated, they were by no means crushed, and ere long we find their khans reigning, now at Samarkand, and now at Bokhara. As time advanced and European powers began to encroach more and more into Asia, the history of the khanates ceases to be confined to the internecine struggles of rival khans. Even Bokhara was not beyond the reach of Russian ambition and English diplomacy. Several European envoys found their way thither during the first half of the present century, and the murder of Stoddart and Connolly in 1842 forms a melancholy episode in British relations with that fanatical capital. With the absorption of the khanate of Bokhara and the capture of Khiva by the Russians the individual history of the Mongol tribes in Central Asia comes to an end, and their name has left its imprint only on the dreary stretch of Chinese-owned country from Manchuria to the Altai Mountains, and to the equally unattractive country in the neighbourhood of the Kökö-nōr. (R. K. D.)

Language and Literature.—The Mongol tongue is a member of the great stock which recent scholars designate as Finno-Tataric or Ural-Altaic, which comprehends also the languages of the Tungoos (Manchu), Turko-Tatars, Finns, and Samoyeds. The members of this group are not so closely related to one another as those of the Indo-European stock; but they are all bound together by the common principle of agglutinative formation, especially the so-called harmony of vowels, by their grammatical structure, and also by certain common elements in the stock of roots which run through them all, or through particular more closely-connected families within the group.[1]

The fatherland proper of the Mongols is the so-called Mongolia. It stretches from Siberia in the north towards the Great Wall of China in the south, from Dauria and Manchuria in the east to the Altai and the sources of the Irtish, Thian-shan (*i.e.*, heaven mountains), and East Turkestan in the west. In the centre of this country is the desert of Gobi (Chinese *Sha-mo, i.e.*, sand-sea). The Mongolian population, however, extends in the south over the Great Wall to the basin of the Kökö-nōr (blue lake), and thence extends due west over Tangut and the northern border of Tibet. Crossing the political frontier, we find Mongols in the Russian province Turkestan, in the territories of Semiryetshensk (land of the seven streams), Alatau, and Semipalatinsk in the west, in the south of the province of Tomsk, with a more populous region due north in Siberia, round the Baikal Lake. The country north of the Gobi, from the Altai, Tangnu, and the Saian mountains in the west to Manchuria in the east, is called Khalkha, with the chief districts Urga (Kürē), Uliassutai, Khobdo (Kobdo). In a north-westerly direction from Gobi, between Thian-shan and the Altai, is Sungaria. The sum total of the Mongol population under Chinese government is calculated at between two and three millions.

Generally the whole Mongol tribe may be divided into three branches: East Mongols, West Mongols, and Buriats.

(1) The East Mongols are divided into the Khalkhas in the borders just mentioned, the Shara Mongols south of the Gobi along the Great Wall north-eastward to Manchuria, and lastly the Shiraigol or Sharaigol in Tangut and in northern Tibet.

(2) On the signification and employment of the different names of the West Mongols (Kalmuks, Oelöd, Oirad or Dörbön Oirad = the four Oirad, Mongol Oirad), and also as regards the subdivision of the tribes, there is much uncertainty. The name Kalmuk, so generally employed among us, is in fact only used by the Volga Kalmuks (Khalimak), but even with them the name is not common, and almost a byname. It is of foreign origin, and most likely a Tatar word which has yet to be explained. *Oirad* means the "near ones," the "related." The usual explanation given is that the single tribes consider themselves as being related to each other, hence *Mongol Oirad*, "the Mongol related tribe." This is the favourite name among Kalmuks. Dörbön Oirad, or the four related tribes, comprise (1) Sungars, (2) Torgod, (3) Khoshod, (4) Dörböd

[1] Compare W. Schott, *Versuch über die tatarischen Sprachen* (Berl., 1836), *Ueber das altaïsche oder finnisch-tatarische Sprachengeschlecht* (Berl., 1849), *Altajische Studien*, Parts i.-v. (Berl., 1860-1870); A. Castrén, *Ethnologische Vorlesungen über die Altaïschen Völker*, edited by A. Schiefner (Petersb., 1857).

of six hours destroyed all the churches, palaces, and houses, with the exception of the Kremlin, within a compass of 30 miles. Thousands of the inhabitants perished in the flames. "The river and ditches about Moscow," says Horsey, "were stopped and filled with the multitudes of people, laden with gold, silver, jewels, chains, ear-rings, and treasures. So many thousands were there burned and drowned that the river could not be cleaned for twelve months afterwards." Satisfied with the destruction he had indirectly caused, and unwilling to attack the Kremlin, the khan withdrew to the Crimea, ravaging the country as he went. Another invasion of Russia, a few years later (1572), was not so fortunate for the Mongols, who suffered a severe defeat near Molody, 50 versts from Moscow. A campaign against Persia made a diversion in the wars which were constantly waged between the Krim khan and the Russians, Cossacks, and Poles. So hardly were these last pressed by their pertinacious enemies in 1649 that they bound themselves by treaty to pay an annual subsidy to the khan. But the fortunes of war were not always on the side of the Tatars, and with the advent of Peter the Great to the Russian throne the power of the Krim Mongols began to decline. In 1696 the czar, supported by a large Cossack force under Mazeppa, took the field against Selim Girai Khan, and gained such successes that the latter was compelled to cede Azoff to him. By a turn of the wheel of fortune the khan had the satisfaction in 1710 of having it restored to him by treaty; but this was the last real success that attended the Tatar arms. In 1735 the Russians in their turn invaded the Crimea, captured the celebrated lines of Perekop, and ravaged Baghchi Serai, the capital. The inevitable fate which was hanging over the Krim Tatars was now being rapidly accomplished. In 1783 the Krim, together with the eastern portion of the land of the Nogais, became absorbed into the Russian province of Taurida.

Another branch of the Mongol family which requires mention is that of the Kazaks (see KIRGHIZ, vol. xiv. pp. 95, 96), whose ancient capital was Sighnak, which, as we have seen, passed into the hands of the great Timur. It will now only be necessary to refer briefly to the Uzbegs, who, on the destruction of the Golden Horde, assumed an important position on the east of the Caspian Sea. The founder of their greatness was the khan Abulkhair, who reigned in the 15th century, and who, like another Jenghiz Khan, consolidated a power out of a number of small clans, and added lustre to it by his successful wars. Sheibani Khan, his grandson, proved himself a worthy successor, and a doughty antagonist of the great Moghul emperor Baber. In 1500 he inflicted a severe defeat on Baber's forces, and captured Samarkand, Herat, and Kandahar. By these and other conquests he became possessed of all the country between the Oxus and the Jaxartes, of Ferghana, Kharezm, and Hissar, as well as of the territory of Tashkend from Kashgar to the frontiers of China. In the following year, by a dashing exploit, Baber recovered Samarkand, but only to lose it again a few months later. During several succeeding years Sheibani's arms proved victorious in many fields of battle, and but for an indiscreet outrage on the territories of the shah of Persia he might have left behind him a powerful empire. The anger, however, of Shah Ismael roused against him a force before which he was destined to fall. The two armies met in the neighbourhood of Merv, where, after a desperate encounter, the Uzbegs were completely defeated. Sheibani, with a few followers, sought refuge in a cattle-pound. But, finding no exit on they cut off the head and presented it to the shah, who caused the skull to be mounted in gold and to be converted into a drinking-cup. After this defeat the Uzbegs withdrew across the Oxus and abandoned Khorásán. Farther east the news aroused Baber to renewed activity, and before long he reoccupied Samarkand and the province "Beyond the River," which had been dominated by the Uzbegs for nine years. But though the Uzbegs were defeated, they were by no means crushed, and ere long we find their khans reigning, now at Samarkand, and now at Bokhara. As time advanced and European powers began to encroach more and more into Asia, the history of the khanates ceases to be confined to the internecine struggles of rival khans. Even Bokhara was not beyond the reach of Russian ambition and English diplomacy. Several European envoys found their way thither during the first half of the present century, and the murder of Stoddart and Connolly in 1842 forms a melancholy episode in British relations with that fanatical capital. With the absorption of the khanate of Bokhara and the capture of Khiva by the Russians the individual history of the Mongol tribes in Central Asia comes to an end, and their name has left its imprint only on the dreary stretch of Chinese-owned country from Manchuria to the Altai Mountains, and to the equally unattractive country in the neighbourhood of the Kokó-nōr. (R. K. D.)

Language and Literature.—The Mongol tongue is a member of the great stock which recent scholars designate as Finno-Tataric or Ural-Altaic, which comprehends also the languages of the Tungoos (Manchu), Turko-Tatars, Finns, and Samoyeds. The members of this group are not so closely related to one another as those of the Indo-European stock; but they are all bound together by the common principle of agglutinative formation, especially the so-called harmony of vowels, by their grammatical structure, and also by certain common elements in the stock of roots which run through them all, or through particular more closely-connected families within the group.[1]

The fatherland proper of the Mongols is the so-called Mongolia. It stretches from Siberia in the north towards the Great Wall of China in the south, from Dauria and Manchuria in the east to the Altai and the sources of the Irtish, Thian-shan (*i.e.*, heaven mountains), and East Turkestan in the west. In the centre of this country is the desert of Gobi (Chinese *Sha-mo*, *i.e.*, sand-sea). The Mongolian population, however, extends in the south over the Great Wall to the basin of the Koko-nōr (blue lake), and thence extends due west over Tangut and the northern border of Tibet. Crossing the political frontier, we find Mongols in the Russian province Turkestan, in the territories of Semiryetshensk (land of the seven streams), Alatau, and Semipalatinsk in the west, in the south of the province of Tomsk, with a more populous region due north in Siberia, round the Baikal Lake. The country north of the Gobi, from the Altai, Tangnu, and the Saian mountains in the west to Manchuria in the east, is called Khalkha, with the chief districts Urga (Kurē), Uliassutai, Khobdo (Kobdo). In a north-westerly direction from Gobi, between Thian-shan and the Altai, is Sungaria. The sum total of the Mongol population under Chinese government is calculated at between two and three millions.

Generally the whole Mongol tribe may be divided into three branches: East Mongols, West Mongols, and Buriats.

(1) The East Mongols are divided into the Khalkhas in the borders just mentioned, the Shara Mongols south of the Gobi along the Great Wall north-eastward to Manchuria, and lastly the Shiraigol or Sharaigol in Tangut and in northern Tibet.

(2) On the signification and employment of the different names of the West Mongols (*Kalmuks*, *Oelod*, *Oirad or Dorbon* Oirad = the four Oirad, Mongol Oirad), and also as regards the subdivision of the tribes, there is much uncertainty. The name Kalmuk, so generally employed among us, is in fact only used by the Volga Kalmuk (Khalimak), but even with them the name is not common, and almost a byname. It is of foreign origin, and most likely a Tatar word which has yet to be explained. *Oirad* means the "near ones," the "related." The usual explanation given is that the single tribes consider themselves as being related to each other, hence *Mongol Oirad*, "the Mongol related tribe." This is the favourite name among Kalmuks. Dorbon Oirad, or the four related tribes, comprise (1) Sungars, (2) Torgod, (3) Khoshod, (4) Dorbod

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same endings in singular and plural. Gender is not indicated. The adjective is uninflected both as attribute and as predicate; there is no comparative form, this idea being expressed by the construction or by the use of certain particles. The personal pronouns are *bi*, I; *tchi*, thou; *bida*, we; *ta*, ye; their genitives serve as possessives. *The demonstratives are ene, tere (this, that)*, plural *ede, tede*; interrogative *ken*, who? The relative is lacking, and its place is supplied by circumlocutions. The numerals are: 1, *nigen*; 2, *khoyar*; 3, *gurban*; 4, *dorben*; 5, *tabun*; 6, *jirgugan*; 7, *dologan*; 8, *naiman*; 9, *yisun*; 10, *arban*; 100, *dsagon*; 1000, *minggan*. The ordinals are formed by appending *tugar, tuger*. The theme of the verb is seen in the imperative, as *bari*, grasp. The conjugation is rich in forms for tense and mood, but person and number are with few exceptions unexpressed. The present is formed from the theme by adding *mui* (*barimui*), the preterite by *bai* or *luga* (*baribai, bariluga*), the future by *ssugai* or *ssu* (*barissugai, barissu*). The preterite has also in the third person the terminations *dsugui* and *rua*; the future has in the third person *yu*, and in the first *ya*. The conditional ends in *bassu* (*baribassu*), the precative in *tugai, tugei*, the potential in *sa* (*barimuisa*), the imperative plural in *ktun*, the gerund in the present in *n*, *dsu* (*barin, baridsu*) or *tala*, "while, till" (*baritala*, "inter capiendum"), in the preterite it is formed in *gad* (*barigad*); the present part. has *ktchi* (*bariktchi*), the past part. *kssan* (*barikssan*); the supine ends in *ra*, the infinitive in *khu* (*barikhu*, or when used substantively *barikhui*). There is but one perfectly regular conjugation, and derivative forms, derived from the theme by infixes, are conjugated on the same scheme. Thus the passive has infixed *ta* or *kda* (*barikdakhu*, to be grasped), the causative *gul* (*barigulkhu*, to cause to grasp), the co-operative or sociative *ltsa* or *lda* (*bariltsakhu*, to grasp together).

There are no prepositions, only post-positions. Adverbs are either simple particles (affirmative, negative, interrogative, modal, &c.), or are formed by suffixes from other parts of speech. There are very few conjunctions; the relations of clauses and sentences are mainly indicated by the verbal forms (part., sup., conditional, but mainly by the gerund).

The order of words and sentences in construction is pretty much the opposite of that which we follow. In a simple sentence the indication of time and place, whether given by an adverb or a substantive with a post-position, always comes first; then comes the subject, always preceded by its adjective or genitive, then the object and other cases depending on the verb, last of all the verb itself preceded by any adverbs that belong to it. So in the structure of a period all causal, hypothetical, concessive clauses, which can be conceived as preceding the main predication in point of time, or even as contemporary with it, or as in any way modifying it, must come first; the finite verb appears only at the end of the main predication or apodosis. The periods are longer than in other languages; a single one may fill several pages.

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Literature.—A clear distinction must be drawn between the higher and nobler written or book-language and the common or conversational language of every day life. The difference between the two is very considerable, and may be fairly compared to that between the Modern High German book-language and the different dialects. All grammars and dictionaries as yet published treat only of the book-language; and so also, with a few exceptions, the published literary documents are written in this higher style. The exceptions are the *Gesser-Khan*, and the *Siddhi Kür* and *Djangariad* (the last two published by Golstunskyi). The popular or conversational language has only quite lately been fixed in writing by A. Pozdnyeyew in his Russian work, *Specimens of the Popular Literature of the Mongolian Tribes*, part i., "Popular Songs" (Petersb., 1880), which contains rich material for the study of the popular literature.

The literature known at present consists mostly of translations from the Tibetan, the holy language of Buddhism, which is still the language of the learned. The Tibetan Buddhist literature is itself translated from the Sanskrit, hence, now and then, through Mongols and Kalmuks we get acquainted with Indian works the originals of which are not known in Sanskrit. Such is the case, for instance, with the tales of Siddhi kür. Many books have also been translated from the Chinese. Most of the writings are of a religious, historical, philosophical, medical, astronomical, or astrological character. Favourite subjects are folk-lore and fairy tales. Among the religious books, perhaps the most important is that containing the legends entitled *uliger un dalai*, "ocean of comparisons" (edited by the late I. Jacob Schmidt under the title, *Der Weise und der Thor*, in Tibetan and German, Petersb., 1843). To this may be added the *boddhi mor*, or "the holy path," the *altan gerel*, "gleaming of gold," the *mani gambo*, and *yertuntchu yin toli*, "mirror of the world." What was known of poetical literature before Pozdnyeyew is scarcely worth mentioning. In some parts of the historical and narrative literature we find, wherever the narrative takes a higher flight, an admixture of poetical diction. The poetry appears in a certain parallelism of the phrases, with a return either of the same endings (rhyme) or of the same words (refrain). Frequently we find, besides the rhyme or refrain, alliteration. The essay of H. C. von der Gabelentz in *Z. f. d. Kunde des Morgenlandes*, vol. i. pp. 20-37, "Einiges über Mongolische Poesie," has been superseded by the work of Pozdnyeyew.

Among historical works a high place is due to that composed by the tribal prince, Ssanang Ssetsen, in the middle of the 17th century (*Geschichte der Ost-Mongolen und ihres Fürstenhauses*, Mong. and Germ., by I. J. Schmidt, Petersb., 1829), and to the *Altan tobtchi*, i.e., "Golden knob" or "precious contents" (text and Russian translation by the Lama Galsang Gomboyew, Petersb., 1858). Of folk lore and fairy tales, we have the legend of the hero *Gesser-Khan* (text ed. by I. J. Schmidt, Petersb., 1836, and German version, 1839, comp. Schott, *Ueber die Sage v. Geser-Khan*, Berl., 1851, and B. Jülg in the *Transactions* of the Würzburger Philol. Versam. of 1868, pp. 58 *sqq.*, Leips., 1869); and the tales about *Ardshi Bordshi* (Russian version by Galsang Gomboyew, Petersb., 1858, text and German trans. by B. Jülg, Innsbr., 1867, 1868). A favourite book is the tales of Siddhi-kür based on the Sanskrit *Vetâla panchavinçati* (Russian trans. by Galsang Gomboyew, Petersb., 1865, nine of the tales in Mongolian and German by B. Jülg, Innsbr., 1868). The fuller collection of these tales in Kalmuk first became known by the German trans. of B. Bergmann in vol. i. of his *Nomadische Streifereien unter d. Kalmuken* (4 vols., Riga, 1804, 1805); an autographed edition in the vulgar dialect was published by C. Golstunskyi (Petersb., 1864, text and German trans. with glossary by B. Jülg, Leips., 1866). *A poetic heroic story is the Djangariad, extracts from which were given by* Bergmann (*op. cit.*, iv. 181 *sqq.*), a complete Russian version by A. Bobrownikow (Petersb., 1854), a German version by F. v. Erdmann in *Z.D.M.G.*, 1857 (Kalmuk text by Golstunskyi, Petersb., 1864). A similar poem is the history of Ubashi Khuntaidshi and his war with the Oirad, Kalmuk text and Russian trans. by G. Gomboyew in his *Altan tobtchi* as above, and text alone autographed by Golstunskyi (Petersb., 1864). Some books of religion for the Christian Buriats (transcribed in Russian characters) represent the Buriatic dialect. The Russian and English Bible Societies have given us a translation of the whole Bible. I. J. Schmidt translated the Gospels and the Acts into Mongolian and Kalmuk for the Russian Bible Society (8 vols., Petersb., 1819-1821),—a masterly work. The English missionaries, E. Stallybrass and W. Swan, and afterwards R. Yuille, translated the whole Old Testament into Mongolian (1836-1840). This work was printed at a mission press erected at great cost for the purpose near Sselenginsk, beyond Lake Baikal in Siberia. In 1846 the New Testament by the same hands appeared at London.

The richest collections of Mongolian and Kalmuk printed books and MSS. are in the Asiatic museum of the Petersburg Academy, and in the libraries of Kasan and Irkutsk; there is also a good collection in the royal library at Dresden. Consult in general, besides the already cited works of Bergmann and Pozdnyeyew, P. S. Pallas, *Sammlungen historischer Nachrichten ü. d. Mongolischen Völkerschaften* (2 vols., Petersb., 1776-1801); I. J. Schmidt, *Forschungen im Gebiete der älteren . . . Bildungsgeschichte der Völker Mittelasiens, vorz. d. Mongolen und Tibeter* (Petersb. and Leips., 1824); B. Jülg, "On the Present State of Mongolian Researches," *Journ. R. As. Soc.*, xiv. (1882), pp. 42-65. (B. J.)

MONGOOS, or MUNGOOS. See ICHNEUMON.

MONITION, in the practice of the English ecclesiastical courts, is an order requiring or admonishing the person complained of to do something specified in the monition, "under pain of the law and penalty thereof." It is the lightest form of ecclesiastical censure, but disobedience to it, after it has been duly and regularly served, entails the penalties of contempt of court. See Phillimore, *Ecclesiastical Law* (London, 1873).

MONK, GEORGE (1608-1669), duke of Albemarle, the second son of Sir Thomas Monk, a gentleman of good family but in embarrassed circumstances, was born at *Potheridge*, near *Torrington in Devonshire, on 6th December* 1608. An exploit which brought him within the reach of the law compelled him to begin his career as a soldier of fortune at the age of seventeen. He acted under Sir R. Grenville as a volunteer in the expedition to Cadiz, and the next year did notable service at the Isle o Rhé.

In 1629 Monk went to the Low Countries, the trainin ground for military men, where in Oxford's and in Goring' regiments he obtained a high reputation for courage an for a thorough knowledge of his trade. In 1638 h threw up his commission in consequence of a quarrel wit the Dutch civil authorities, came to England, and obtaine the lieutenant-colonelcy of Newport's regiment during t operations on the Scottish border. Here he showed hi skill and coolness in the dispositions by which he save the English artillery at Newborn, though himself destitut of ammunition; and in the councils of war he confident voted with Strafford for fighting, and against retreat c composition. One of Monk's biographers relates that h now thought of joining the adventurers who propose t colonize Madagascar. The Irish rebellion, however, offere

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Among historical works a high place is due to that composed by the tribal prince, Ssanang Ssetsen, in the middle of the 17th century (*Geschichte der Ost-Mongolen und ihres Fürstenhauses*, Mong. and Germ., by I. J. Schmidt, Petersb., 1829), and to the *Altan tobtchi*, i.e., "Golden knob" or "precious contents" (text and Russian translation by the Lama Galsang Gomboyew, Petersb., 1858). Of folk lore and fairy tales, we have the legend of the hero *Gesser-Khan* (text ed. by I. J. Schmidt, Petersb., 1836, and German version, 1839, comp. Schott, *Ueber die Sage v. Geser-Khan*, Berl., 1851, and B. Jülg in the *Transactions* of the Würzburger Philol. Versam. of 1868, pp. 58 *sqq.*, Leips., 1869); and the tales about *Ardshi Bordshi* (Russian version by Galsang Gomboyew, Petersb., 1858, text and German trans. by B. Jülg, Innsbr., 1867, 1868). A favourite book is the tales of Siddhi-kür based on the Sanskrit *Vetâla panchavinçati* (Russian trans. by Galsang Gomboyew, Petersb., 1865, nine of the tales in Mongolian and German by B. Jülg, Innsbr., 1868). The fuller collection of these tales in Kalmuk first became known by the German trans. of B. Bergmann in vol. i. of his *Nomadische Streifereien unter d. Kalmuken* (4 vols., Riga, 1804, 1805); an autographed edition in the vulgar dialect was published by C. Golstunskyi (Petersb., 1864, text and German trans. with glossary by B. Jülg, Leips., 1866). A poetic heroic story is the *Djangariad*, extracts from which were given by Bergmann (*op. cit.*, iv. 181 *sqq.*), a complete Russian version by A. Bobrownikow (Petersb., 1854), a German version by F. v. Erdmann in *Z.D.M.G.*, 1857 (Kalmuk text by Golstunskyi, Petersb., 1864). A similar poem is the history of Ubashi Khuntaidshi and his war with the Oirad, Kalmuk text and Russian trans. by G. Gomboyew in his *Altan tobtchi* as above, and text alone autographed by Golstunskyi (Petersb., 1864). Some books of religion for the Christian Buriats (transcribed in Russian characters) represent the Buriatic dialect. The Russian and English Bible Societies have given us a translation of the whole Bible. I. J. Schmidt translated the Gospels and the Acts into Mongolian and Kalmuk for the Russian Bible Society (8 vols., Petersb., 1819-1821),—a masterly work. The English missionaries, E. Stallybrass and W. Swan, and afterwards R. Yuille, translated the whole Old Testament into Mongolian (1836-1840). This work was printed at a mission press erected at great cost for the purpose near Sselenginsk, beyond Lake Baikal in Siberia. In 1846 the New Testament by the same hands appeared at London.

The richest collections of Mongolian and Kalmuk printed books and MSS. are in the Asiatic museum of the Petersburg Academy, and in the libraries of Kasan and Irkutsk; there is also a good collection in the royal library at Dresden. Consult in general, besides the already cited works of Bergmann and Pozdnyeyew, P. S. Pallas, *Sammlungen historischer Nachrichten ü. d. Mongolischen Völkerschaften* (2 vols., Petersb., 1776-1801); I. J. Schmidt, *Forschungen im Gebiete der älteren . . . Bildungsgeschichte der Völker Mittelasiens, vorz. d. Mongolen und Tibeter* (Petersb. and Leips., 1824); B. Jülg, "On the Present State of Mongolian Researches," *Journ. R. As. Soc.*, xiv. (1882), pp. 42-65. (B. J.)

MONGOOS, or MUNGOOS. See ICHNEUMON.

MONITION, in the practice of the English ecclesiastical courts, is an order requiring or admonishing the person complained of to do something specified in the monition, "under pain of the law and penalty thereof." It is the lightest form of ecclesiastical censure, but disobedience to it, after it has been duly and regularly served, entails the penalties of contempt of court. See Phillimore, *Ecclesiastical Law* (London, 1873).

MONK, GEORGE (1608-1669), duke of Albemarle, the second son of Sir Thomas Monk, a gentleman of good family but in embarrassed circumstances, was born at Potheridge, near Torrington in Devonshire, on 6th December 1608. An exploit which brought him within the reach of the law compelled him to begin his career as a soldier of fortune at the age of seventeen. He acted under Sir R. Grenville as a volunteer in the expedition to Cadiz, and the next year did notable service at the Isle o Rhé.

In 1629 Monk went to the Low Countries, the trainin ground for military men, where in Oxford's and in Goring' regiments he obtained a high reputation for courage an for a thorough knowledge of his trade. In 1638 h threw up his commission in consequence of a quarrel wit the Dutch civil authorities, came to England, and obtaine the lieutenant-colonelcy of Newport's regiment during t operations on the Scottish border. Here he showed hi skill and coolness in the dispositions by which he save the English artillery at Newborn, though himself destitut of ammunition; and in the councils of war he confident voted with Strafford for fighting, and against retreat c composition. One of Monk's biographers relates that h now thought of joining the adventurers who proposed t colonize Madagascar. The Irish rebellion, however, offere

ment, in accordance with his desire, had arranged for its dispersion that he would enter with his troops. Even now his intentions were strictly concealed; the spies set upon him by the various anxious parties were baffled by his impenetrable reserve. He was careful to appear only as the servant of parliament, but when he was desired to take the oath of abjuration he skilfully evaded the request. The city, always jealous of the Rump, now refused to pay taxes except at the orders of a free parliament. Monk, in consequence, was ordered to march his troops into the city, take down the chains and posts, and unhinge the gates. He obeyed these unpleasant orders to the letter on 10th February, thus permitting the hatred against the Rump to rise to the height, while he showed how unwilling an instrument of its will he was. On the 11th, however, he threw off the mask, and wrote to the Rump, peremptorily ordering them to admit the secluded members, and to arrange for the dissolution of parliament by 6th May. On 21st February he conducted the secluded members to their seats. At the same time he refused to restore the Lords, and issued an order disowning Charles Stuart to all officers commanding garrisons. Every day brought him fresh opportunities for tact or evasion. His partisans urged him to take the protectorate himself; another party pressed upon him to accomplish the restoration by the army alone; a body of his officers sent him a declaration expressing their fears that his action would lead to the restoration of monarchy; the parliament tried to make him their own by the offer of Hampton Court. His trained habits of dissimulation and evasion, assisted now and again by downright lying, carried him triumphantly through all these dangers, and at length the dissolution of parliament on 17th March removed his greatest difficulties.

It was now that, with the utmost secrecy, he gave an interview for the first time to the king's agent Grenvil, and by him sent to Charles the conditions of his restoration, afterwards embodied in the Declaration of Breda. For himself at present he would accept nothing but a royal commission as captain-general, which he carefully kept to himself. All parties were anxious to gain the credit of the now certain restoration. The Presbyterians in particular, fearful of the king being restored without terms, did their best to discredit Monk and to impose the old Isle of Wight conditions; but in vain. The new parliament was elected, and the House of Lords restored; an insurrection by Lambert, who had escaped from the Tower, was quelled by Monk's prompt measures, and on the 25th of April he received the solemn thanks of both Houses, and the title of captain-general of the land forces. Even yet the farce was kept up. Monk received with feigned surprise the king's official letter from Grenvil, denied all knowledge of its contents, and handed it over sealed to the council, who decided to defer opening it until the meeting of parliament on the 1st of May.

With the Restoration the historic interest of Monk's career ceases. The rude soldier of fortune had played the game with incomparable dexterity, and had won the stakes. He was made gentleman of the bedchamber, knight of the Garter, master of the horse, commander-in-chief, and duke of Albemarle, and had a pension of £7000 a year allotted him. His utmost desires were satisfied, and he made no attempt to compete further in a society in which neither he nor his vulgar wife could ever be at home, and which he heartily despised. As long as the army existed of which he was the idol, and of which the last service was to suppress Venner's revolt, he was a person not to be displeased. But he entirely concurred in the measure for disbanding it, and thenceforward his influence was small, though men's eyes turned naturally to him in emergency. In the trial of the regicides he was on the side of moderation, and his interposition saved Hazelrig's life; but his action at the time of Argyll's trial will always be regarded as the most dishonourable episode in his career. In 1664 he had charge of the admiralty when James was in command of the fleet, and when in 1665 London was deserted on account of the plague, Monk, with all the readiness of a man accustomed to obey without thinking of risk, remained in charge of the government of the city. Once more, at the end of this year, he was called upon to fight, having a joint commission with Prince Rupert against the Dutch. The whole burden of the preparations fell upon him. On 23d April 1666 the admirals joined the fleet, and on the 1st of June began a battle near Dunkirk which lasted four days, followed by another on 23d July, in which Monk showed all his old coolness and skill, and a reckless daring which had seemed hitherto foreign to his character. His last service was in 1667, when the Dutch fleet sailed up the Thames, and Monk, ill as he was, hastened to Chatham to oppose their further progress. From that time he lived much in privacy, and died of dropsy on the 3d of December 1669.

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MONKEY. See Ape.

MONMOUTH, a maritime county of England. is bounded E. by Gloucester, N.E. by Hereford, N.W. by Brecknock, W. and S.W. by Glamorgan, and S. by the Bristol Channel. Its greatest length from north to south is about 35 miles, and its greatest breadth about 28 miles. The area is 368,399 acres, or about 572 square miles.

The surface of Monmouth is very varied, and in many districts picturesque, especially along the valley of the Wye, and between that river and the Usk. In the west and north the hills rise to a considerable height, and this mountain region encircles a finely undulating country. The highest summits are Sugar Loaf (1954 feet), Blorenge (1908), and Skyridd Vawr (1601). Along the shore on both sides of the Usk are two extensive tracts of marsh land, called the Caldicot and Wentllooge levels, stretching from Cardiff to Portskewett, and protected from inundations by strong embankments.

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Geology and Minerals.—The geological formation is principally Old Red Sandstone and Carboniferous,—the Old Red forming the larger and eastern half of the county, from a line drawn between Abergavenny and Newport, and varying in thickness from between 8000 and 10,000 feet in the north to about 4000 feet in the south. In the centre of the county adjoining the Usk there is an outcrop of Silurian rocks, extending to a distance of about 8 miles north and south and 4 miles east and west, with a thickness of 1500 feet. Towards the east the Old Sandstone rocks dip beneath the Mountain Limestone, which enters the county from the Forest of Dean coal-field, and gives its peculiar character to the fine scenery along the banks of the Wye. The formation varies in thickness from

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Monmouth was one of the strongholds of the Saxons; and under the name of Blestium formed one of the stations of the Romans. It was incorporated by Edward VI., and received additional privileges from Queen Mary, James I., and Charles II. It has sent members to parliament since the 27th of Henry VIII., and, along with Newport and Usk, forms the Monmouth district of boroughs. The area of the municipal and parliamentary borough is 4983 acres, with a population in 1871 of 5879, and in 1881 of 6111.

MONMOUTH, a small manufacturing city of the United States, in Warren county, Illinois, 180 miles south-west of Chicago by the main line of the Chicago, Burlington, and Quincy Railroad, and 182 miles north of St Louis, by the St Louis division of the same railway. The Iowa Central Railway passes through the city. An opera-house and Monmouth College are among the principal buildings. The population increased from 4662 in 1870 to 5000 in 1880. The city charter dates from 1852.

MONMOUTH, JAMES, DUKE OF (1649-1685), was the son of Lucy Walters, "a brown, beautiful, bold, but insipid creature," who became the mistress of Charles II. during his exile at the Hague. He was born at Rotterdam on 9th April 1649. That Charles was his father is more than doubtful, for Lucy Walters had previously lived with Robert Sidney, brother of Algernon, and the boy resembled him very closely. Charles, however, always recognized him as his son, and lavished on him an almost doting affection. Until the Restoration he was placed under the care, first of Lord Crofts, and then of the queen-dowager, receiving his education to the age of nine from Roman Catholics, but thenceforward from Protestant tutors. In July 1662 he was sent for by Charles, and at thirteen was placed under the protection of Lady Castlemaine and in the full tide of the worst influences of the court. No formal acknowledgment of his relation to the king was made until his betrothal to Anne Scott, daughter of the earl of Buccleuch, and the wealthiest heiress of Scotland, whom he married in 1665. During 1663 he was made duke of Orkney, duke of Monmouth, and knight of the Garter, and received honorary degrees at both universities. At court he was treated as a prince of the blood. In 1665 he served with credit under the duke of York in the sanguinary naval battle off Lowestoft. A captaincy in the Life Guards was given him, and in 1670, on the death of Monk, he was made captain-general of the king's forces. Offices of wealth also were showered upon him, and he was admitted to the privy council. In 1670 Monmouth was with the court at Dover, and it is affirmed by Reresby that the mysterious death of Charles's sister, the duchess of Orleans, was due to her husband's revenge on the discovery of her intrigue with the duke. It is certain, from an entry by Pepys, that as early as 1666 he had established a character for vice and profligacy. He was the direct author of the attack in December 1670 on Sir John Coventry, and only a few months later received the royal pardon for his share in the wanton murder of a street watchman. De Gramont, in his vivid sketch of Monmouth, after describing the beauty and bodily prowess for which he was celebrated, notices the fatal emptiness and poverty of his mind: "Tous les avantages du corps parloient pour lui; mais son esprit ne disait pas un petit mot en sa faveur. Il n'avait de sentimens que ce qu'on lui en inspirait."

Hitherto Monmouth had been but the spoiled child of a wicked court. Now, however, by no act or will of his own, he began to be a person politically important. As early as 1662 the king's excessive fondness for him had caused anxiety. Even then the fear of a "difference" between Monmouth and James, duke of York, exercised men's minds; and every caress or promotion kept the fear alive. Who could tell but that, in default of legitimate issue from his queen, Charles might declare Monmouth himself his lawful son? A civil war would be the certain consequence. Soon after 1670 the matter took a more serious aspect. The anti-popery spirit was rapidly becoming a frenzy, and the succession of James a probability and a terror. Charles was urged to legitimize Monmouth by a declaration of his marriage with Lucy Walters. He returned answer that, much as he loved the duke, he would rather see him hanged at Tyburn than own him for his legitimate son. Every attempt, however, was henceforth made, especially by Shaftesbury, to accustom people to this idea. He was taught to regard himself as the representative of the Protestant interest, and his position was emphasized by James's second marriage with the Roman Catholic princess Mary of Modena. From this time his popular title was "the Protestant duke." Charles was induced to confer many prominent employments upon him. The influence of James, however, was strong enough to prevent his obtaining the lord-lieutenancy of Ireland; but he received the command of the 6000 troops who assisted the French in the second Dutch war, and, though without any claims to generalship, behaved with courage in the field. In 1674 he was made "commander-in-chief;" and, in connexion with this, another unsuccessful attempt, graphically described in Clarke's *Life of James*, was made to gain from Charles a tacit admission of his legitimacy. At Shaftesbury's instance he was placed in command of the army employed in 1675 against the Scottish Covenanters, and was present at Bothwell Bridge (22d June 1679). He was also, at the king's request, elected chancellor of the university of Cambridge. In 1678, when Charles was driven into war with Louis, Monmouth took the command of the English contingent, and again gained credit for personal courage at the battle of St Denis. On his return to London England was in the throes of the popish terror. The idea of securing the Protestant succession by legitimizing Monmouth again took shape and was eagerly pressed on by Shaftesbury; at the time it seemed possible that success would wait on the audacity.

The Pensionary parliament was dissolved in January 1678-79, and was succeeded by one still more determined in its anti-popery spirit. To avoid the storm, and to save, if possible, his brother's interests, Charles instructed him to leave the country. James retired to Brussels, the king having previously signed a declaration that he "never was married, nor gave contract to any woman whatsoever but to my wife Queen Catherine." In spite of this, Monmouth might naturally now nourish ambitious views. His rival was off the stage; Shaftesbury, his chief supporter, was president of the remodelled privy council; and he himself was the favourite of the city. In the summer of 1679 the king suddenly fell ill, and the dangers of a disputed succession became terribly apparent. The party opposed to Monmouth, or rather to Shaftesbury, easily prevailed upon Charles to consent to his brother's temporary return. When, after the king's recovery, James went back to Brussels, he received a promise that Monmouth too should be removed from favour and ordered to leave the country. Accordingly, in September 1679 the latter repaired to Utrecht, while shortly afterward James's friends so far gained ground as to obtain for [illegible] permission to reside at Edinburgh instead of at Brussels. Within two months of his arrival at Utrecht, Monmouth secretly returned to England, arriving in London on 27th

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MONMOUTH, JAMES, DUKE OF (1649-1685), was the son of Lucy Walters, "a brown, beautiful, bold, but insipid creature," who became the mistress of Charles II. during his exile at the Hague. He was born at Rotterdam on 9th April 1649. That Charles was his father is more than doubtful, for Lucy Walters had previously lived with Robert Sidney, brother of Algernon, and the boy resembled him very closely. Charles, however, always recognized him as his son, and lavished on him an almost doting affection. Until the Restoration he was placed under the care, first of Lord Crofts, and then of the queen-dowager, receiving his education to the age of nine from Roman Catholics, but thenceforward from Protestant tutors. In July 1662 he was sent for by Charles, and at thirteen was placed under the protection of Lady Castlemaine and in the full tide of the worst influences of the court. No formal acknowledgment of his relation to the king was made until his betrothal to Anne Scott, daughter of the earl of Buccleuch, and the wealthiest heiress of Scotland, whom he married in 1665. During 1663 he was made duke of Orkney, duke of Monmouth, and knight of the Garter, and received honorary degrees at both universities. At court he was treated as a prince of the blood. In 1665 he served with credit under the duke of York in the sanguinary naval battle off Lowestoft. A captaincy in the Life Guards was given him, and in 1670, on the death of Monk, he was made captain-general of the king's forces. Offices of wealth also were showered upon him, and he was admitted to the privy council. In 1670 Monmouth was with the court at Dover, and it is affirmed by Reresby that the mysterious death of Charles's sister, the duchess of Orleans, was due to her husband's revenge on the discovery of her intrigue with the duke. It is certain, from an entry by Pepys, that as early as 1666 he had established a character for vice and profligacy. He was the direct author of the attack in December 1670 on Sir John Coventry, and only a few months later received the royal pardon for his share in the wanton murder of a street watchman. De Gramont, in his vivid sketch of Monmouth, after describing the beauty and bodily prowess for which he was celebrated, notices the fatal emptiness and poverty of his mind: "Tous les avantages du corps parloient pour lui; mais son esprit ne disait pas un petit mot en sa faveur. Il n'avait de sentimens que ce qu'on lui en inspirait."

Hitherto Monmouth had been but the spoiled child of a wicked court. Now, however, by no act or will of his own, he began to be a person politically important. As early as 1662 the king's excessive fondness for him had caused anxiety. Even then the fear of a "difference" between Monmouth and James, duke of York, exercised men's minds; and every caress or promotion kept the fear alive. Who could tell but that, in default of legitimate issue from his queen, Charles might declare Monmouth himself his lawful son? A civil war would be the certain consequence. Soon after 1670 the matter took a more serious aspect. The anti-popery spirit was rapidly becoming a frenzy, and the succession of James a probability and a terror. Charles was urged to legitimize Monmouth by a declaration of his marriage with Lucy Walters. He returned answer that, much as he loved the duke, he would rather see him hanged at Tyburn than own him for his legitimate son. Every attempt, however, was henceforth made, especially by Shaftesbury, to accustom people to this idea. He was taught to regard himself as the representative of the Protestant interest, and his position was emphasized by James's second marriage with the Roman Catholic princess Mary of Modena. From this time his popular title was "the Protestant duke." Charles was induced to confer many prominent employments upon him. The influence of James, however, was strong enough to prevent his obtaining the lord-lieutenancy of Ireland; but he received the command of the 6000 troops who assisted the French in the second Dutch war, and, though without any claims to generalship, behaved with courage in the field. In 1674 he was made "commander-in-chief;" and, in connexion with this, another unsuccessful attempt, graphically described in Clarke's *Life of James*, was made to gain from Charles a tacit admission of his legitimacy. At Shaftesbury's instance he was placed in command of the army employed in 1675 against the Scottish Covenanters, and was present at Bothwell Bridge (22d June 1679). He was also, at the king's request, elected chancellor of the university of Cambridge. In 1678, when Charles was driven into war with Louis, Monmouth took the command of the English contingent, and again gained credit for personal courage at the battle of St Denis. On his return to London England was in the throes of the popish terror. The idea of securing the Protestant succession by legitimizing Monmouth again took shape and was eagerly pressed on by Shaftesbury; at the time it seemed possible that success would wait on the audacity.

The Pensionary parliament was dissolved in January 1678-79, and was succeeded by one still more determined in its anti-popery spirit. To avoid the storm, and to save, if possible, his brother's interests, Charles instructed him to leave the country. James retired to Brussels, the king having previously signed a declaration that he "never was married, nor gave contract to any woman whatsoever but to my wife Queen Catherine." In spite of this, Monmouth might naturally now nourish ambitious views. His rival was off the stage; Shaftesbury, his chief supporter, was president of the remodelled privy council; and he himself was the favourite of the city. In the summer of 1679 the king suddenly fell ill, and the dangers of a disputed succession became terribly apparent. The party opposed to Monmouth, or rather to Shaftesbury, easily prevailed upon Charles to consent to his brother's temporary return. When, after the king's recovery, James went back to Brussels, he received a promise that Monmouth too should be removed from favour and ordered to leave the country. Accordingly, in September 1679 the latter repaired to Utrecht, while shortly afterward James's friends so far gained ground as to obtain for [illegible] permission to reside at Edinburgh instead of at Brussel[illegible] Within two months of his arrival at Utrecht, Mo[illegible] secretly returned to England, arriving in London on 27[illegible]

guards. The attempt, however, miscarried; and, after summoning Bath in vain, Monmouth, with a disordered force, began his retrograde march through Philips-Norton and Frome, continually harassed by Feversham's soldiers. At the latter place he heard of Argyll's total rout in the western Highlands. He was now anxious to give up the enterprise, but was overruled by Grey, Wade, and others. On the 3d of July he reached Bridgwater again, with an army little better than a rabble, living at free quarters and behaving with reckless violence. On Sunday the 5th Feversham entered Sedgemoor in pursuit; Monmouth the same night attempted a surprise, but his troops were hopelessly routed. He himself, with Grey and a few others, fled over the Mendip Hills to the New Forest, hoping to reach the coast and escape by sea. The whole country, however, was on the alert, and at midnight on the 8th, within a month of their landing, James heard that the revolt, desperate from the first, was over, and that his rival had been captured close to Ringwood, in Hampshire.

The poor strain in Monmouth's character was now shown. On the day of his capture he wrote to James in terms of the most unmanly contrition, ascribing his wrongdoings to the action of others, and imploring an interview. On the 13th the prisoners reached the Tower, and on the next day Monmouth was allowed to see James. The accounts of this interview are difficult to reconcile in some points, but all agree that Monmouth's behaviour was unmanly in the extreme. No mercy was shown him, nor did he in the least deserve mercy; he had wantonly attacked the peace of the country, and had cruelly libelled James. The king had not, even in his own mind, any family tie to restrain him from exercising just severity, for he had never believed Monmouth to be the son of any one but Robert Sidney. Two painful interviews followed with the wife for whom he bore no love, and who for him could feel no respect; another imploring letter was sent to the king, and abject protestations and beseechings were made to all whom he saw. He offered, as the last hope, to become a Roman Catholic, and this might possibly have proved successful, but the priests sent by James to ascertain the sincerity of his "conversion" declared that he cared only for his life and not for his soul.

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MONMOUTH, Geoffrey of. See Geoffrey of Monmouth.

MONOPHYSITES. See Eutyches and Jacobite Church.

MONOPOLI, a city of Italy, in the province of Bari, is situated on the coast of the Adriatic, 25 miles by rail south-east of Bari. It is a bishop's see, is surrounded by ancient walls, and possesses a castle built by Charles V. in 1552, a cathedral, and a hospital dating from 1368. The harbour is neither large nor well protected, but a certain amount of trade is carried on in the export of local products. The population was about 12,000 in the 17th century; 12,377 in 1861; and 13,000 in 1871, that of the commune being 20,918. Monopoli probably grew up after the destruction of Egnatia (5th century), the ruins of which lie a few miles to the south.

MONOPOLY (μονοπωλία, *exclusive sale*). Though still used in the sense of the original Greek, the term is more accurately applied only to grants from the crown or from parliament, the private act of an individual whereby he obtains control over the supply of any particular article being properly defined as "engrossing." It was from the practice of the sovereign granting to a favourite, or as a reward for good service, a monopoly in the sale or manufacture of some particular class of goods that the system of protecting inventions arose, and this fact lends additional interest to the history of monopolies (see Patents). When the practice of making such grants first arose it does not appear easy to say. Sir Edward Coke laid it down that by the ancient common law the king could grant to an inventor, or to the importer of an invention from abroad, a temporary monopoly in his invention, but that grants in restraint of trade were illegal. Such, too, was the law laid down in the first recorded case, Darcy *v.* Allin (the case of monopolies, 1602), and this decision was never overruled, though the law was frequently evaded. The patent rolls of the Plantagenets show few instances of grants of monopolies (the earliest known is temp. Edw. III.), and we come down to the reign of Henry VIII. before we find much evidence of this exercise of the prerogative in the case of either new inventions or known articles of trade. Elizabeth, as is well known, granted patents of monopoly so freely that the practice became a grave abuse, and on several occasions gave rise to serious complaints in the House of Commons. Lists prepared at the time show that many of the commonest necessaries of life were the subjects of monopolies, by which their price was grievously enhanced. That the queen did not assume the right of making these grants entirely at her pleasure is shown, not only by her own statements in answer to addresses from the House, but by the fact that the preambles to the instruments conveying the grants always set forth some public benefit to be derived from their action. Thus a grant of a monopoly to sell playing-cards is made, because "divers subjects of able bodies, which might go to plough, did employ themselves in the art of making of cards"; and one for the sale of starch is justified on the ground that it would prevent wheat being wasted for the purpose. Accounts of the angry debates in 1565 and 1601 are given in Hume and elsewhere. The former debate produced a promise from the queen that she would be careful in exercising her privileges; the latter a proclamation which, received with great joy by the House, really had but little effect in stopping the abuses complained of. A few grants were cancelled, others limited, and others again left to the action of the ordinary law courts (instead of the privy council). In speaking of the results of the proclamation, previous writers seem to have been misled by the promises made in the queen's speech, promises by no means carried out in the text of the document itself, a copy of which still exists in the British Museum.

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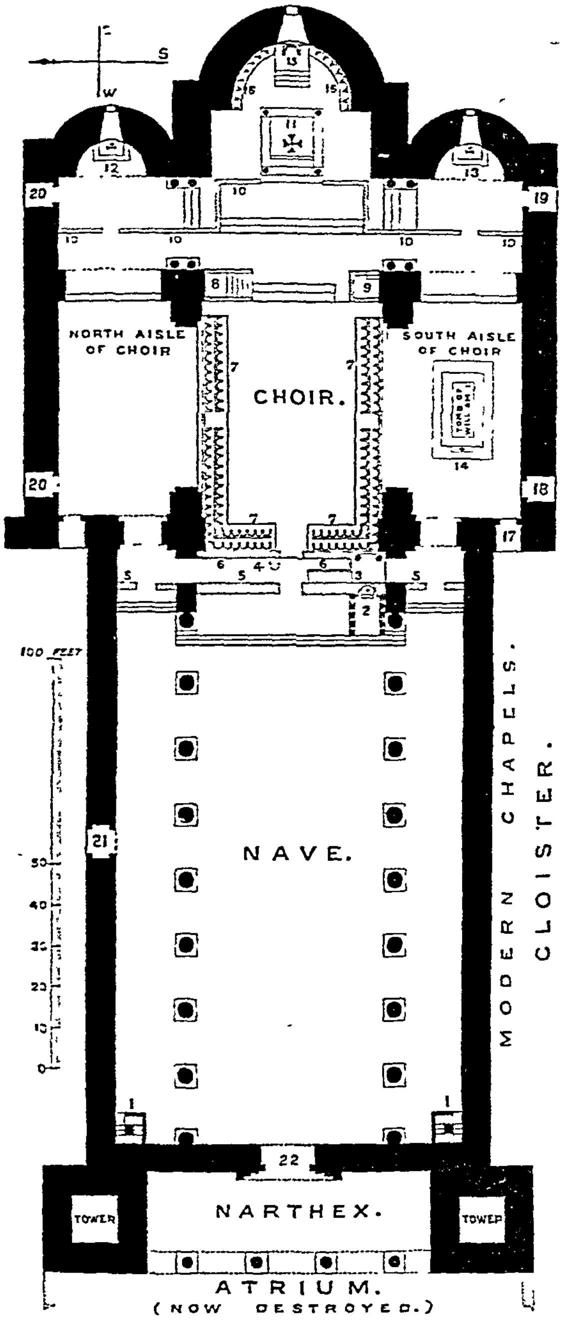

Plan of the cathedral of Monreale, as built in the 12th century, omitting later additions.

- 1, 1. Stairs to towers, now altered.
- 2. Chapel under the south ambo.
- 3. Stairs to ambo.
- 4. Holy-water stoup.
- 5, 5. "Pulpitum" or choir-screen, now destroyed.
- 6, 6. Screens behind stalls, now destroyed.
- 7, 7. Stalls, now destroyed.
- 8. King's throne.
- 9. Archbishop's throne.
- 10, 10. Sanctuary screen.
- 11. High altar and baldacchino.
- 12. Altar in northern apse.
- 13. Altar in southern apse.
- 14. Altar at tomb of William I.
- 15. Archbishop's throne.
- 16, 16. Seats for clergy.
- 17. Door to great cloister.
- 18. Door to chapter house.
- 19. Door to sacristy.
- 20, 20. Doors to royal palace.
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The chief feature of the place—the church—like the main cloister, is fortunately well preserved. In plan it is a curious mixture of Eastern and Western arrangement (see fig.). The nave is like an Italian basilica, while the large triple-apsed choir is like one of the early three-apsed churches, of which so many examples still exist in Syria and other Eastern countries (see De Vogüé, *Syrie Centrale*). It is, in fact, like two quite different churches put together endwise. The basilican nave is wide, with narrow aisles. Monolithic columns of Oriental granite (except one, which is of cipollino), evidently the spoils of older buildings, on each side support eight pointed arches much stilted. There is no triforium, but a high clerestory with wide two-light windows, with simple tracery like those in the nave-aisles and throughout the church. The other half, Eastern in two senses, is both wider and higher than the nave. It also is divided into a central space with two aisles, each of the divisions ending at the east with an apse. The roofs throughout are of open woodwork very low in pitch, constructionally plain, but richly decorated with colour, now mostly restored. At the west end of the nave are two projecting towers, with narthex-entrance between them. A large open atrium, which once existed at the west, is now completely destroyed. The outside of the church is plain, except the aisle walls and three eastern apses, which are decorated with intersecting pointed arches and other ornaments inlaid in marble. The outsides of the principal doorways and their pointed arches are magnificently enriched with carving and inlay, a curious combination of three styles—Norman-French, Byzantine, and Arab.

It is, however, the enormous extent (80,630 square feet) and glittering splendour of the glass mosaics covering the interior, which make this church so marvellously splendid (see MOSAIC). With the exception of a high dado, itself very beautiful, made of marble slabs enriched with bands of mosaic, the whole interior surface of the walls, including soffits and jambs of all the arches, is covered with minute mosaic-pictures in brilliant colours on a gold ground. This gorgeous method of decoration takes the place of all purely architectural detail, such as mouldings and panelling. The mosaic covers even the edges of the arches and jambs, which are slightly rounded off, so as to allow them to be covered by the glass tesseræ. This device gives apparent softness to all the edges, and greatly enhances the richness of effect produced by the gleaming gold grounds. The only carving inside is on the sculptured caps of the nave arcade, mostly Corinthian in style. The mosaic pictures are arranged in tiers, divided by horizontal and vertical bands of elaborate flowing mosaic ornament. In parts of the choir there are five of these tiers of subjects or single figures one above another. The half dome of the central apse has a colossal half-length figure of Christ, with a seated Virgin and Child below; the other apses have full-length colossal figures of St Peter and St Paul. Inscriptions on each picture explain the subject or saint represented; these are in Latin, except some few which are in Greek. The subjects are partly from the *Old Testament* types of Christ and His scheme of redemption, with figures of those who prophesied and prepared for His coming. Towards the east are subjects from the New Testament, chiefly representing Christ's miracles and suffering, with apostles, evangelists, and other saints. The design, execution, and choice of subjects all appear to be of Byzantine origin, the subjects being selected from the *Menologium* drawn up by the emperor Basilius Porphyrogenitus in the 10th century.

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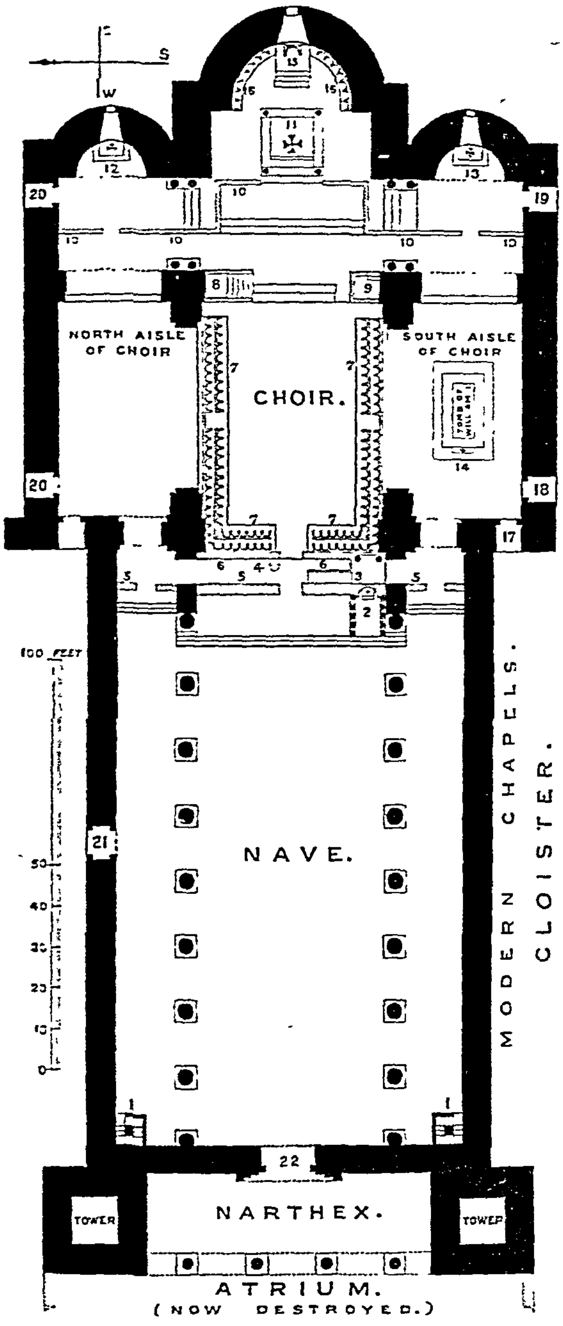

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MONROE, a city of the United States, county seat of Monroe county, Michigan, lies 32 miles south-south-west of Detroit, on both banks of the Raisin river, 3 miles inland from Lake Erie, with which it has been connected by a ship-canal since 1843. It is a station on the Canada Southern, the Flint and Père Marquette, and the Detroit division of the Lake Shore and Michigan Southern Railways. Agricultural implement factories, a spoke and hub factory, foundries and engineering-works, carriage-works, grist-mills, paper-mills, and fruit-drying establishments are in operation. From 400 to 500 tons of grapes are shipped yearly from the neighbouring vineyards, and over 100,000 gallons of wine are made here. The population in 1880 was 4928. Settled as Frenchtown by a body of Canadians in 1784, Monroe received its present name, in honour of President Monroe, in 1817. Its city charter dates from 1837. It was the scene of the battle of the river Raisin, 22d January 1813.

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Monstrosities from Defective Closure in the Middle Line.—Under this head come some of the commonest congenital malformations, including slight deficiencies such as harelip, and serious defects such as a gap in the crown of the head with absence of the brain. The embryo is originally a circular flattened disc spread out on one pole of the yolk, and it is formed into a cylindrical body (with four appendages) by the free margins of the disc, or rather its ventral laminæ, folding inwards to meet in the middle line and so close in the pelvic, abdominal, thoracic, pharyngeal, and oral cavities. Meanwhile, and indeed rather earlier, two longitudinal parallel ridges on the top or along the back of the disc have grown up and united in the middle line to form the second barrel of the body—the neural canal—of small and uniform width in the lower three-fourths or spinal region, but expanding into a wide chamber for the brain. This division into neural (dorsal) and hæmal (ventral) canals underlies all vertebrate development. Imperfect closure along either of those embryonic lines of junction may produce various degrees of monstrosity. The simplest and commonest form, hardly to be reckoned in the present category, is harelip with or without cleft palate, which results from defective closure of the ventral laminæ at their extreme upper end. Another simple form, but of much more serious import, is a gap left in the neural canal at its lower end; usually the arches of the lumbar vertebræ are deficient, and the fluid that surrounds the spinal cord bulges out in its membranes, producing a soft tumour under the skin at the lower part of the back. This is the condition known as *hydrorhachis*, depending on the osseous defect known as *spina bifida*. Children born with this defect are difficult to rear, and are very likely to die in a few days or weeks. More rarely the gap in the arches of the vertebræ is in the region of the neck. If it extend all along the back, it will probably involve the skull also. Deficiency of the crown of the head, and in the spine as well, may be not always traceable to want of formative power to close the canal in the middle line; an over-distended condition of the central water-canal and water-spaces of the cord and brain may prevent the closure of the bones, and ultimately lead to the disruption of the nervous organs themselves; and injuries to the mother, with inflammation set up in the fœtus and its appendages, may be the more remote cause. But it is by defect in the middle line that the mischief manifests itself, and it is in that anatomical category that the malformations are included. The osseous deficiency at the crown of the head is usually accompanied by want of the scalp, as well as of the brain and membranes. The bones of the face may be well developed and the features regular, except that the eyeballs bulge forward under the closed lids; but there is an abrupt horizontal line above the orbits where the bones cease, the skin of the brow joining on to a spongy kind of tissue that occupies the sides and floor of the cranium. This is the commonest form of an *anencephalous* or brainless monster. There are generally mere traces of the brain, although, in some rare and curious instances, the hemispheres are developed in an exposed position on the back of the neck. The cranial nerves are usually perfect, with the exception sometimes of the optic (and retina). Vegetative existence is not impossible, and a brainless monster has been known to survive sixty-five days. The child is usually a very large one.

Closely allied, as we have seen, to the anencephalous condition is the condition of congenital *hydrocephalus*. The nervous system at its beginning is a neural canal, not only as regards its bony covering, but in its interior; a wide space lined by ciliated epithelium and filled with water extends along the axis of the spinal cord, and expands into a series of water-chambers in the brain. As development proceeds, the walls thicken at the expense of the internal water-spaces, the original tubular or chambered plan of the central nervous system is departed from, and those organs assume the practically solid form in which we familiarly know them. If, however, the water-spaces persist in their embryonic proportions notwithstanding the thickening of the nervous substance forming their walls, there results an enormous brain which is more than half occupied inside with water, contained in spaces tha[t] correspond on the whole to the ventricles of the brai[n] as normally bounded. A hydrocephalic fœtus may sur[-]vive its birth, and will be more apt to be affected in [its] nutrition than in its intelligence. In many cases t[he] hydrocephalic condition does not come on till after t[he] child is born. The *microcephalous* condition, where it [is] not a part of cretinism, is not usually a congenital de[fect] in the strict sense, but more often a consequence of t[he]

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tions, there are others of them referable to the effects of mechanical pressure, and even to direct amputation of parts within the uterus.

Acardiac and Acranial Monsters.—It sometimes happens in a twin pregnancy that one of the embryos fails to develop a heart and a complete vascular system of its own, depending for its nourishment upon blood derived from the placenta of its well-formed twin by means of its umbilical vessels. It grows into a more or less shapeless mass, in which all traces of the human form may be lost. Other viscera besides the heart will be wanting, and no head distinguishable; the most likely parts to keep the line of development are the lumbar region (with the kidneys), the pelvis, and the lower limbs. The twin of this monster may be a healthy infant.

Reversed Position of the Viscera.—This is a developmental error depending on the retention of the right aortic arch as in birds, instead of the left as is usual in mammals. The position of all the unsymmetrical viscera is transposed, the spleen and cardiac end of the stomach going to the right side, the liver to the left, the cæcum resting on the left iliac fossa, and the sigmoid flexure of the colon being attached to the right. This condition of *situs inversus viscerum* need cause no inconvenience; and it will probably remain undetected until the occasion should arise for a physical diagnosis or *post-mortem* inspection. There are numerous other anomalies in the development of the great vessels. In the heart itself there may be an imperfect septum ventriculorum, and there is more frequently a patency of the fœtal communication between the auricles, permitting the venous blood to pass into the arterial system, and producing the livid appearance of the face known as *cyanosis*.

The causes of congenital anomalies are difficult to specify. There is no doubt that, in some cases, they are present in the sperm or germ of the parent; the same anomalies recur in several children of a family, and it has been found possible, through a variation of the circumstances, to trace the influence in some cases to the father alone, and in other cases to the mother alone. The remarkable thing in this parental influence is that the malformation in the child may not have been manifested in the body of either parent, or in the grandparents. More often the malformation is acquired by the embryo and fœtus in the course of development and growth, either through the mother or in itself independently. Maternal impressions during pregnancy have often been alleged as a cause, and this causation has been discussed at great length by the best authorities. The general opinion seems to be that it is impossible to set aside the influence of subjective states of the mother altogether. The doctrine of maternal impressions has often been resorted to when any other explanation was either difficult or inconvenient; thus, Hippocrates is said to have saved the virtue of a woman who gave birth to a black child by pointing out that there was a picture of a negro on the wall of her chamber. Injuries to the mother during pregnancy have been unquestionably the cause of certain malformations, especially of congenital hydrocephalus. The embryo itself and its membranes may become the subject of inflammations, atrophies, hypertrophies, and the like; this causation, to which Otto traced all malformations of the fœtus, is doubtless accountable for a good many of them. But a very large residue of malformations must still be referred to no more definite cause than the erratic spontaneity of the embryonic cells and cell-groups. The *nisus formativus* of the fertilized ovum is always made subject to morphological laws, but, just as in extra-uterine life, there may be deviations from the beaten track; and even a slight deviation at an early stage will carry with it far-reaching consequences. This is particularly noticeable in double monsters.

2. *Double Monsters.*—Twins are the physiological analogy of double monsters, and some of the latter have come very near to being two separate individuals. Triple monsters are too rare to dwell upon, but their analogy would be triplets. The Siamese twins, who died in 1874 at the age of sixty, were joined only by a thick fleshy ligament from the lower end of the breast-bone (xiphoid cartilage), having the common navel on its lower border; the anatomical examination showed, however, that a process of peritoneum extended through the ligament from one abdominal cavity to the other, and that the blood-vessels of the two livers were in free communication across the same bridge. There are one or two cases on record in which such a ligament has been cut at birth, one, at least, of the twins surviving. From the most intelligible form of double monstrosity, like the Siamese twins, there are all grades of fantastic fusion of two individuals into one down to the truly marvellous condition of a small body or fragment parasitic upon a well-grown infant,—the condition known as *fœtus in fœtu*. These monstrosities are deviations, not from the usual kind of twin gestation, but from a certain rarer physiological type of dual development. In by far the majority of cases twins have separate uterine appendages, and have probably been developed from distinct ova; but in a small proportion of (recorded) cases there is evidence, in the placental and enclosing structures, that the twins had been developed from two rudiments arising side by side on a single blastoderm. It is to the latter physiological category that double monsters almost certainly belong; and there is some direct embryological evidence for this opinion. Allen Thomson observed in the blastoderm of a hen's egg at the sixteenth or eighteenth hour of incubation two "primitive traces" or rudiments of the backbone forming side by side; and in a goose's egg incubated five days he found on one blastoderm two embryos, each with the rudiments of upper and lower extremities, crossing or cohering in the region of the future neck, and with only one heart between them. Somewhat similar observations had been previously published (four cases in all) by Wolff, Von Baer, and Reichert. Malformations in the earliest stages of the blastoderm have been more frequently observed of late, especially in the ova of the pike; and these point not so much to a symmetrical doubling of the primitive trace as to irregular budding from the margin of the germinal disc. In any case, the perfect physiological type appears to be two rudiments on one blastoderm, whose entirely separate development produces twins (under their rarer circumstances), whose nearly separate development produces such double monsters as the Siamese twins, and whose less separate development produces the various grotesque forms of two individuals in one body. There can be no question of a literal fusion of two embryos; either the individuality of each was at no time complete, or, if there were two distinct primitive traces, the uni-axial type was approximately reverted to in the process of development, as in the formation of the abdominal and thoracic viscera, limbs, pelvis, or head. Double monsters are divided in the first instance into those in which the doubling is symmetrical and equal on the two sides, and those in which a small or fragmentary fœtus is attached to or enclosed in a fœtus of average development,—the latter class being the so-called cases of "parasitism."

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Montaigne (as was not unnatural in a man of his temperament, who had for some years, if not for the greater part of his life, lived solely to please himself) was not altogether delighted at his election to the mayoralty, which promised him two years of responsible if not very hard work. The memory of his father, however, and the commands of the king, which seem to have been expressed in a manner rather stronger than a mere formal confirmation, induced him to accept it; and he seems to have discharged it neither better nor worse than an average magistrate. Indeed, he gave sufficient satisfaction to the citizens to be re-elected at the close of his term, and it may be suspected that the honour of the position, which was really one of considerable dignity and importance, was not altogether indifferent to him. Unfortunately, it cannot be said that nothing in his office became him like the leaving of it, for it was at the close of his second tenure that he gave the only sign of the demoralizing effect which is sometimes alleged by severe moralists to come of the half epicurean, half sceptical philosophy which he undoubtedly professed. It was his business, if not exactly his duty, to preside at the formal election of his successor, the maréchal de Matignon; but there was a severe pestilence in Bordeaux, and Montaigne writes to the jurats of that town, in one of the few undoubtedly authentic letters which we possess, to the effect that he will leave them to judge whether his presence at the election is so necessary as to make it worth his while to expose himself to the danger of going into the town in its then condition, "which is specially dangerous for men coming from a good air as he does." That is to say, the chief magistrate of one of the greatest towns in France not only declined to visit it because of sickness prevailing there, but had left it to itself at a time when nearly half the population perished, and when, according to the manners of the age, civil disturbance was almost sure to follow accordingly. Attempts have been made to justify Montaigne, and it may be at least said that he at no time pretended to unselfish heroism; but it is to be feared that the facts and the inference drawn from them admit of no dispute. At the least, Montaigne's conduct must be allowed to contrast very little to his advantage with that of Rotrou in the next century under somewhat similar circumstances though in a position of much less responsibility. It may, however, be urged in Montaigne's favour that the general circumstances of the time, where they did not produce reckless and foolhardy daring, almost necessarily produced a somewhat excessive caution. The League was on the point of attaining its greatest power; the extreme Calvinist and Navarrese party, on the other side, was (as may be seen in Agrippa d'Aubigné) no less fanatical than the League itself, and the salvation of France seemed to lie in the third party of *politiques*, or trimmers, to which Montaigne belonged. The capital motto of this party was that of the Scotch saying, "Jouk and let the jaw gang by," and the continual habit of parrying and avoiding political dangers might be apt to extend itself to dangers other than political. However this may be, Montaigne had difficulty enough during this turbulent period, all the more so from his neighbourhood to the chief haunts and possessions of Henry of Navarre. He was able, however, despite the occupations of his journey, his mayoralty, and the pressure of civil war and pestilence, which was not confined to the town, to continue his essay writing, and in 1588, after a visit of some length to Paris, the third book of the *Essays* was published, together with the former ones considerably revised. The new essays, as has been remarked, differ strikingly from the older ones in respect of length; there being only one which confines itself to the average of those in the first two books. The whimsical unexpectedness of the titles, moreover, reappears in but two of them: "Des coches" and "Des boiteux." They are, however, identical with the earlier ones in spirit, and make with them a harmonious whole—a book which has hardly been second in influence to any of the modern world.

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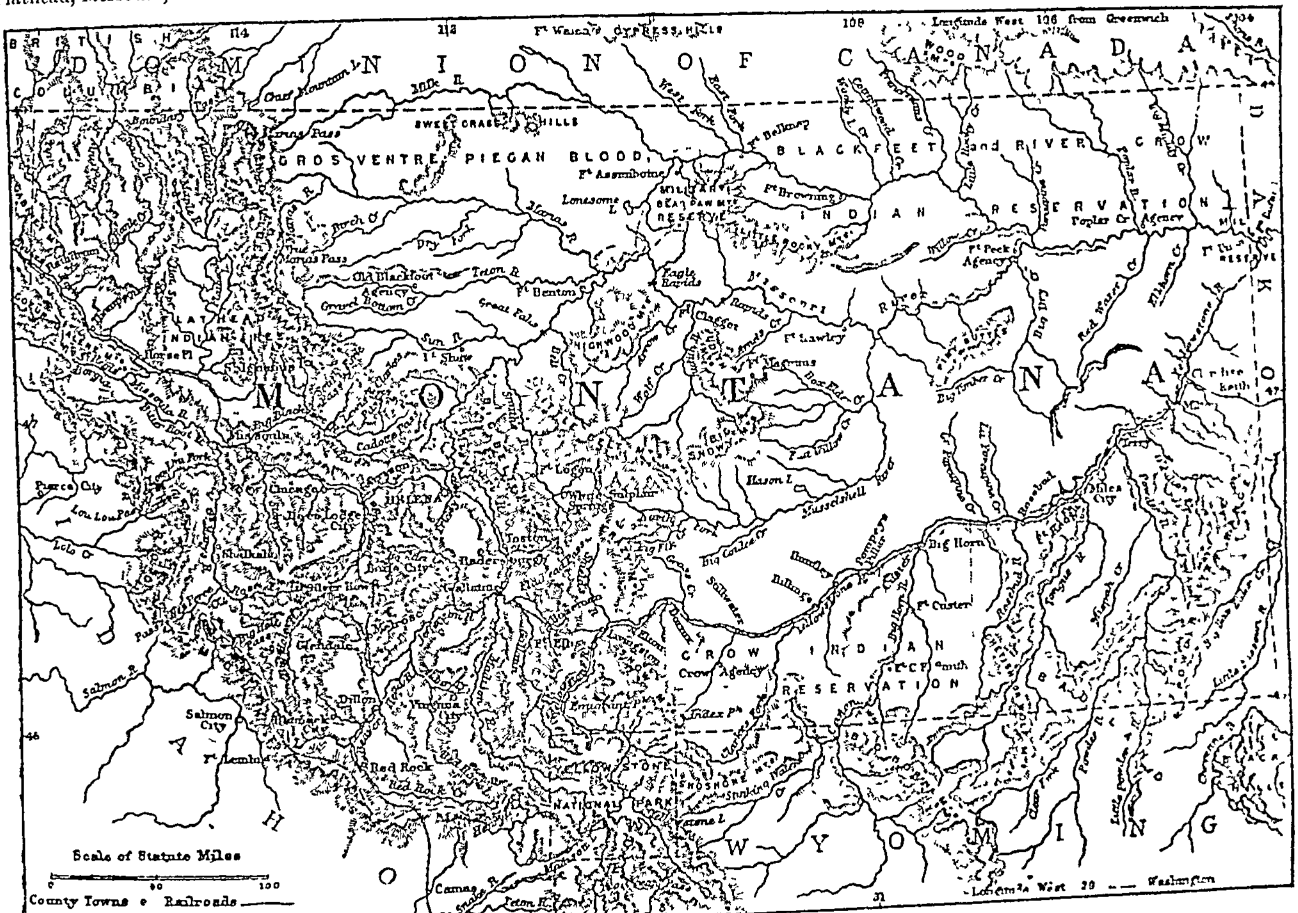
base of the Bitter-root Mountains into Idaho. This stream is very rapid, and is not navigable. Its course, as well as those of most of its tributaries, passes through narrow valleys, the surrounding country being well watered and covered with dense forests of *Coniferæ*.

Geology.—Most of the mountain area belongs to the Eozoic and Silurian formations. Along the base of the mountains is a Triassic belt of variable width. Succeeding this is a broad area of nearly horizontal Cretaceous beds, followed by the Tertiary formation, which covers nearly one-third of the Territory. These recent formations are interrupted here and there by volcanic upheavals.

Climate.—The climate of Montana differs almost as greatly in different parts of the Territory as that of California. In the north-west it resembles that of the Pacific coast. The westerly winds blowing off the Pacific do not meet with as formidable a barrier as farther south, and consequently are not chilled, or deprived of so large a proportion of their moisture. The result is that the north-western portion of Montana enjoys a mild temperature and a rainfall sufficient for the needs of agriculture. The valleys of the Kootenai, Flathead, Missoula, and Bitter-root can be cultivated without irrigation with little danger of loss from drought. Farther east and south the rainfall decreases. In the valleys of the upper Missouri, the Jefferson, Madison, Gallatin, and the upper Yellowstone irrigation is almost everywhere required, as well as over the broad extent of the plains. Over most of the Territory the rainfall ranges from 10 to 15 inches annually; in the north-western corner it rises to 25.

The general temperature is comparatively mild for the latitude, the elevation above the sea being decidedly less than that of the average of the Rocky Mountain region. The mean annual temperature ranges from 40° to 50° Fahr., but the variations are very great and violent. Frosts and snowstorms are possible during every month of the year, so that agriculture and stock-raising are more or less hazardous. On the other hand, the ordinary extremes of temperature are not so great as in more arid portions of the country.

Forests.—Throughout the Territory, as everywhere else in the Cordilleran region, forests follow rainfall. The plains are treeless; the mountain valleys about the heads of the Missouri are clothed only with grass and artemisia, many localities extending to a considerable height up the mountains, which are themselves timbered, though not heavily. In the north-western part, roughly defined as the drainage area of Clark's Fork, where the rainfall is somewhat greater, the forests become of importance. The mountains are forest-



Sketch Map of Montana Territory.

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Fauna.—The native fauna is not sharply distinguished from that of neighbouring States and Territories. The higher latitude is, however, indicated by the relatively greater abundance of species favouring a colder climate. The moose and the Rocky Mountain goat, though by no means abundant, still frequent chosen haunts in the mountains,—the former in the cool marshy valleys, the latter upon the most rugged inaccessible elevations. The black-tailed and mule deer, the antelope, elk, and mountain sheep are abundant, and the bison still ranges the plains, though in sadly reduced numbers. Among *Carnivoræ*, the black and grizzly bears, mountain lion, lynx, wild cat, and several species of wolves are still plentiful.

Agriculture and Industry.—Agriculture is dependent in most parts of Montana upon the supply of water furnished by the streams. Owing to this fact it is probable that not more than 8 per cent. of the total area of the Territory can ever, even under the most economical distribution of the water-supply, be brought under cultivation. In the drainage area of Clark's Fork are several fine valleys containing a considerable extent of arable land, such as those of the Missoula, Bitter-root, Deer Lodge, Jocko, and Flathead. Upon the head-waters of the Missouri is also a large extent of arable land. The valleys of the Jefferson and Madison also deserve mention. Along the eastern base of the mountains, near the head-waters of the Sun, Teton, and Marias rivers, are considerable areas susceptible of irrigation. Below the Forks the Missouri flows for 75 miles through a broad valley, much of which can be irrigated; below Fort Benton, however, the bluffs become higher and close in on the river. The Yellowstone, also, after leaving the mountains, flows through a similar kind of valley, which extends with a few minor breaks down to the point where the river turns from an east to a north-east course, when it enters a country of *mauvaises terres*, which, except as a mausoleum of fossil remains, is utterly valueless.

Owing to the comparatively isolated position of the Territory, agricultural pursuits have been limited by the demands of home consumption. The census of 1880 reported the area in farms to consist of 405,683 acres, with an average of 267 acres to each farm. The whole is less than one-half per cent. of the entire area of the Territory. The improved land is reported as amounting to 262,611 acres. The following are the amounts of the principal agricultural products:—wheat, 469,688 bushels; maize, 5689 bushels; oats,

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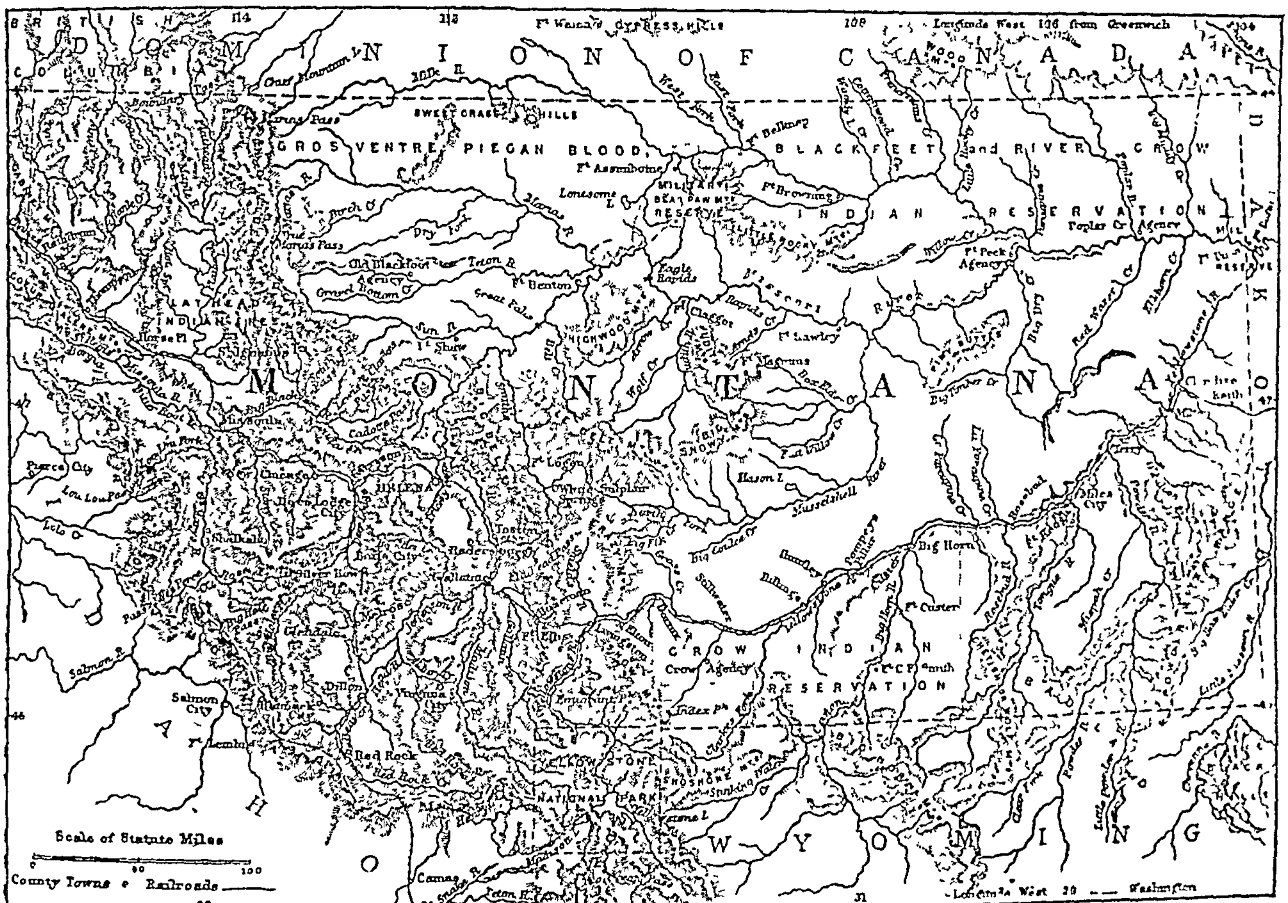

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church at large was given over to worldliness, that she had forsaken the old paths and entered on a way that must lead to destruction. The writings of Tertullian afford the clearest demonstration that what is called Montanism was a reaction against secularism in the church, and an effort to conserve the privileges of primitive Christianity. At the same time, they show no less clearly that Montanism in Carthage was a very different thing from the Montanism of Montanus. Western Montanism, at the beginning of the 3d century, admitted the legitimacy of almost every point of the Catholic system. It allowed that the bishops were the successors of the apostles, that the Catholic rule of faith was a complete and authoritative exposition of Christianity, and that the New Testament was the supreme rule of the Christian life. How, then, one may well ask, was it possible to separate from the Catholic Church? On what ground could the separation be justified? How could it be said that a new era of the Spirit had come in when the Spirit had already given all necessary instructions in the Scriptures of the New Testament? And what claim could be thought to exceed the legitimate rights of the successors of the apostles? Montanus himself and his first disciples had been in quite a different position. In his time there was no fixed, divinely-instituted congregational organization, no canon of New Testament Scriptures, no anti-Gnostic theology, and no Catholic Church. There were simply certain communities of believers bound together by a common hope, and by a free organization, which might be modified to any required extent. When Montanus proposed to summon all true Christians to Pepuza, in order to live a holy life and prepare for the day of the Lord, there was nothing whatever to prevent the execution of his plan except the inertia and lukewarmness of Christendom. But this was not the case in the West at the beginning of the 3d century. At Rome and Carthage, and in all other places where sincere Montanists were found, they were confronted by the imposing edifice of the Catholic Church, and they had neither the courage nor the inclination to undermine her sacred foundations. This explains how the later Montanism never attained a position of influence. In accepting, with slight reservations, the results of the development which the church had undergone during the fifty years from 160 to 210 it reduced itself to the level of a sect. For, if the standpoint of the Catholic Church is once acknowledged, then Montanism is an innovation; and if the canon of the New Testament is accepted the doctrine of a new era of the Spirit is heresy. Tertullian exhausted the resources of dialectic in the endeavour to define and vindicate the relation of the spiritualists to the "psychic" Christians; but no one will say he has succeeded in clearing the Montanistic position of its fundamental inconsistency.

Of the later history of Montanism very little is known. But it is at least a significant fact that prophecy could not be resuscitated. Montanus, Prisca, and Maximilla were always recognized as the inspired authorities. At rare intervals a vision might perhaps be vouchsafed to some Montanistic old woman, or a brother might now and then have a dream that seemed to be of supernatural origin; but the overmastering power of religious enthusiasm was a thing of which the Montanists knew as little as the Catholics. Their discipline was attended with equally disappointing results. In place of an intense moral earnestness binding itself by its own strict laws, we find in Tertullian a legal casuistry, a finical morality, from which no good could ever come. It was only in the land of its nativity that Montanism held its ground till the 4th century. It maintained itself there in a number of close communities, probably in places where no Catholic congregation had been formed; and to these the Novatians at a later period attached themselves. In Carthage there existed down the year 400 a sect called Tertullianists; and in this comparatively late survival we have a striking test[...] to the influence of the great Carthaginian teacher. [...] doctrinal questions there was no real difference betw[een] the Catholics and the Montanists. The early Montan[ists] (the prophets themselves) used expressions which [...] to indicate a Monarchian conception of the person [of] Christ. After the close of the 2d century we find sections amongst the Western Montanists, just as [...] the Western Catholics,—there were some who adopted [the] Logos-Christology, and others who remained Monarch[ian].

Sources.—The materials for the history of Montanism, alt[hough] plentiful, are fragmentary, and require a good deal of sifting. They may be divided into four groups. (1) The utter[ances] of Montanus, Prisca, and Maximilla[1] are our most important [...] but unfortunately they consist of only twenty-one short sayi[ngs]. (2) The works written by Tertullian after he became a Mon[tanist] furnish the most copious information,—not, however, about [the] first stages of the movement, but only about its later phase, [after] the Catholic Church was established. (3) The oldest p[...] works of the 2d century, extracts from which have been pre[served] especially by Eusebius (*Hist. Eccles.*, bk. v.), form the next gr[oup]. These must be used with the utmost caution, because even [the] earliest orthodox writers give currency to many misconceptions [and] calumnies. (4) The later lists of heretics, and the casual not[ices] of church fathers from the 3d to the 5th century, though not [con]taining much that is of value, yet contain a little.[2]

Literature.—Ritschl's investigations, referred to above, s[uper]sede the older works of Tillemont, Wernsdorf, Mosheim, W[...], Neander, Baur, and Schwegler (*Der Montanismus und die ch[rist]liche Kirche des 2ten Jahrhunderts*, Tubingen, 1841). The later wo[rks], of which the best and most exhaustive is that of Bonwetsch, *Geschichte des Montanismus*, 1881, all follow the lines laid d[own by] Ritschl. See also, Gottwald, *De Montanismo Tertulliani*, 1[...]; Réville, "Tertullien et le Montanisme" in the *Revue des Deux Mo[ndes]*, 1st November 1864; Stroelin, *Essai sur le Montanisme*, 1870; Soyres, *Montanism and the Primitive Church*, London, 1878; Cunningham, *The Churches of Asia*, London, 1880; Renan, "Crises du Catholicisme Naissant" in *Rev. d. Deux Mondes*, 15th [Feb]ruary 1881; Möller, art. "Montanismus" in Herzog's *Th[eol.] Realencyklop.*, 2d ed. Special points of importance in the his[tory of] Montanism have been quite recently investigated by Lipsius, C[...]beck, Weizsäcker (*Theol. Lit.-Zeitung*, Nr. 4, 1882), and [...] (*Das Mönchthum, seine Ideale und seine Geschichte*, 2d ed., 1882, *Z. f. Kircheng.*, iii. pp. 369-408). Weizsäcker's short essays [are] extremely valuable, and have elucidated several important p[oints] hitherto overlooked. (A. HA.)

MONTARGIS, chief town of an arrondissement in [the] department of Loiret, France, lies 40 miles east-north-[east] of Orleans on the railway from Paris to Lyons. Trave[rsed] by the Loing, Montargis belongs to the basin of the Sei[ne], but it communicates with the Loire by the Orleans [and] the Briare canals. It has a fine church (Ste Magde[leine]), dating in part from the 12th century, a museum, an[d a] public library; and it still preserves portions of its [...] magnificent castle, which was capable of containing 60[00] men, and, previous to the erection of Fontainebleau, wa[s so] favourite a residence of the royal family that it acquired [the] title of "Berceau des Enfans de la France." Paper-mak[ing] (introduced in the beginning of the 18th century) [and] several other considerable industries are carried on. [The] population of both commune and town was 9175 in 18[...].

Montargis (*Mons Argi* or *Algi*, *M. Arginus*, *Montargium*) [was] formerly the capital of the Gâtinais (*Pagus Vastinensis*). Hav[ing] passed in 1188 from the Courtenai family to Philip August[us, it] long formed part of the royal domain. In 1528 Francis I. mortga[ged the] town, castle, and forest (this last a tract of great value) to Re[née] d'Este, daughter of Louis XII., the famous Huguenot princess; in 1570 Charles IX. gave them in full property to her daughter An[ne], through whom they descended to the dukes of Guise, but they w[ere] repurchased for the crown in 1612. Montargis was several ti[mes] taken or attacked by the English in the 15th century, and is par[ti]cularly proud of the successful defence it made in 1427. Both Cha[rles] VII. and Charles VIII. held court in the town; it was the latter w[ho] set the famous Dog of Montargis to fight a duel with his maste[r's] murderer whom he had tracked and captured.

[1] Collected by Munter, and by Bonwetsch, *Geschichte des Mon[tan]ismus*, p. 197 *sq*.

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church at large was given over to worldliness, that she had forsaken the old paths and entered on a way that must lead to destruction. The writings of Tertullian afford the clearest demonstration that what is called Montanism was a reaction against secularism in the church, and an effort to conserve the privileges of primitive Christianity. At the same time, they show no less clearly that Montanism in Carthage was a very different thing from the Montanism of Montanus. Western Montanism, at the beginning of the 3d century, admitted the legitimacy of almost every point of the Catholic system. It allowed that the bishops were the successors of the apostles, that the Catholic rule of faith was a complete and authoritative exposition of Christianity, and that the New Testament was the supreme rule of the Christian life. How, then, one may well ask, was it possible to separate from the Catholic Church? On what ground could the separation be justified? How could it be said that a new era of the Spirit had come in when the Spirit had already given all necessary instructions in the Scriptures of the New Testament? And what claim could be thought to exceed the legitimate rights of the successors of the apostles? Montanus himself and his first disciples had been in quite a different position. In his time there was no fixed, divinely-instituted congregational organization, no canon of New Testament Scriptures, no anti-Gnostic theology, and no Catholic Church. There were simply certain communities of believers bound together by a common hope, and by a free organization, which might be modified to any required extent. When Montanus proposed to summon all true Christians to Pepuza, in order to live a holy life and prepare for the day of the Lord, there was nothing whatever to prevent the execution of his plan except the inertia and lukewarmness of Christendom. But this was not the case in the West at the beginning of the 3d century. At Rome and Carthage, and in all other places where sincere Montanists were found, they were confronted by the imposing edifice of the Catholic Church, and they had neither the courage nor the inclination to undermine her sacred foundations. This explains how the later Montanism never attained a position of influence. In accepting, with slight reservations, the results of the development which the church had undergone during the fifty years from 160 to 210 it reduced itself to the level of a sect. For, if the standpoint of the Catholic Church is once acknowledged, then Montanism is an innovation; and if the canon of the New Testament is accepted the doctrine of a new era of the Spirit is heresy. Tertullian exhausted the resources of dialectic in the endeavour to define and vindicate the relation of the spiritualists to the "psychic" Christians; but no one will say he has succeeded in clearing the Montanistic position of its fundamental inconsistency.

Of the later history of Montanism very little is known. But it is at least a significant fact that prophecy could not be resuscitated. Montanus, Prisca, and Maximilla were always recognized as the inspired authorities. At rare intervals a vision might perhaps be vouchsafed to some Montanistic old woman, or a brother might now and then have a dream that seemed to be of supernatural origin; but the overmastering power of religious enthusiasm was a thing of which the Montanists knew as little as the Catholics. Their discipline was attended with equally disappointing results. In place of an intense moral earnestness binding itself by its own strict laws, we find in Tertullian a legal casuistry, a finical morality, from which no good could ever come. It was only in the land of its nativity that Montanism held its ground till the 4th century. It maintained itself there in a number of close communities, probably in places where no Catholic congregation had been formed; and to these the Novatians at a later period attached themselves. In Carthage there existed down the year 400 a sect called Tertullianists; and in comparatively late survival we have a striking test to the influence of the great Carthaginian teacher. doctrinal questions there was no real difference betw the Catholics and the Montanists. The early Montan (the prophets themselves) used expressions which to indicate a Monarchian conception of the person Christ. After the close of the 2d century we find sections amongst the Western Montanists, just as the Western Catholics,—there were some who adopted Logos-Christology, and others who remained Monarch

Sources.—The materials for the history of Montanism, alt plentiful, are fragmentary, and require a good deal of sifting. They may be divided into four groups. (1) The uttern of Montanus, Prisca, and Maximilla[1] are our most important but unfortunately they consist of only twenty-one short sayi (2) The works written by Tertullian after he became a Mon furnish the most copious information,—not, however, about first stages of the movement, but only about its later phase, the Catholic Church was established. (3) The oldest p works of the 2d century, extracts from which have been pre especially by Eusebius (*Hist. Eccles.*, bk. v.), form the next gr These must be used with the utmost caution, because even earliest orthodox writers give currency to many misconceptions calumnies. (4) The later lists of heretics, and the casual not of church fathers from the 3d to the 5th century, though not taining much that is of value, yet contain a little.[2]

Literature.—Ritschl's investigations, referred to above, s sede the older works of Tillemont, Wernsdorf, Mosheim, W Neander, Baur, and Schwegler (*Der Montanismus und die ch liche Kirche des 2ten Jahrhunderts*, Tubingen, 1841). The later wo of which the best and most exhaustive is that of Bonwetsch, *Geschichte des Montanismus*, 1881, all follow the lines laid d Ritschl. See also, Gottwald, *De Montanismo Tertulliani*, Réville, "Tertullien et le Montanisme" in the *Revue des Deux Mo* 1st November 1864; Stroelin, *Essai sur le Montanisme*, 1870; Soyres, *Montanism and the Primitive Church*, London, 1878; Cunningham, *The Churches of Asia*, London, 1880; Renan, " Crises du Catholicisme Naissant" in *Rev. d. Deux Mondes*, 15th ruary 1881; Möller, art. "Montanismus" in Herzog's *Th Realencyklop.*, 2d ed. Special points of importance in the his Montanism have been quite recently investigated by Lipsius, C beck, Weizsäcker (*Theol. Lit.-Zeitung*, Nr. 4, 1882), and ern (*Das Mönchthum, seine Ideale und seine Geschichte*, 2d ed., 1882, *Z. f. Kircheng.*, iii. pp. 369-408). Weizsäcker's short essays extremely valuable, and have elucidated several important p hitherto overlooked. (A. HA.

MONTARGIS, chief town of an arrondissement in department of Loiret, France, lies 40 miles east-north- of Orleans on the railway from Paris to Lyons. Trave by the Loing, Montargis belongs to the basin of the Sei but it communicates with the Loire by the Orleans the Briare canals. It has a fine church (Ste Magde dating in part from the 12th century, a museum, an public library; and it still preserves portions of its c magnificent castle, which was capable of containing 60 men, and, previous to the erection of Fontainebleau, wa favourite a residence of the royal family that it acquired title of "Berceau des Enfans de la France." Paper-ma (introduced in the beginning of the 18th century) several other considerable industries are carried on. population of both commune and town was 9175 in 18

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travelling in Europe, Montesquieu not only satirized unmercifully the social, political, ecclesiastical, and literary follies of his day in France, but indulged in a great deal of the free writing (so free as very nearly to deserve the term licentious) which was characteristic of the tale-tellers of the time. But what scandalized grave and precise readers naturally attracted the majority, and the *Lettres Persanes* were very popular, passing, it is said, through four editions within the year, besides piracies. Then the vogue suddenly ceased, or at least editions ceased for nearly nine years to appear. It is said that a formal ministerial prohibition was the cause of this, and it is not improbable; for, though the regent and Dubois must have enjoyed the book thoroughly, they were both shrewd enough to perceive that underneath its playful exterior there lay a spirit of very inconvenient criticism of abuses in church and state. The fact is that the *Lettres Persanes* is the first book of what is called the Philosophe movement. The criticism is scarcely yet aggressive, much less destructive, and in Montesquieu's hands it never became so; but what it might become in the hands of others was obvious enough. It is this precursorship in his own special line which in all probability made Voltaire so jealous of Montesquieu, as well as the advantage which a wealthy and well-born noble of high official position had over himself. It is amusing to find Voltaire describing the *Lettres* as a "trumpery book," a "book which anybody might have written easily." It is not certain that, in its peculiar mixture of light badinage with not merely serious purpose but gentlemanlike moderation, Voltaire could have written it himself, and it is certain that no one else at that time could. 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The sole edition of Montesquieu which need be mentioned here is that of Édouard Laboulaye (7 vols., Paris, 1875-1879), the sole biography that of Louis Vian (Paris, second edition, 1879). From the latter the facts of the above notice are principally drawn. *The bibliography of Montesquieu's published works is not of any special interest, but in respect of anecdota he occupies a singular position.* There is known to exist at La Brède a great mass of MSS materials for the *Esprit des Lois*, additional *Lettres Persanes*, essays and fragments of all kinds, diaries, letters, notebooks, and so forth. *The present possessors,* however, who represent Montesquieu, though not in the direct male line, have hitherto refused permission to examine these to all editors and critics, though the publication of some of them has been vaguely promised. At present they are chiefly known by a paper contributed nearly *half a century ago to the Transactions* of the Academy of Agen (1834). (G. SA.)

MONTEVERDE, Claudio (1568-1643), the inventor of the "free style" of musical composition, was born at Cremona in 1568; he was engaged at an early age as violist to the duke of Mantua, and studied composition with some success under Ingegneri, the duke's "maestro di capella," though without thoroughly mastering the difficulties of musical science. His knowledge of counterpoint was limited, and his ear imperfect, but he was a bold experimenter, and his undisguised empiricism led to discoveries which exercised a lasting influence upon the progress of art. He was the first composer who ventured to use unprepared dissonances,—employing them first in his madrigals, the beauty of which they utterly destroyed, but afterwards introducing them into music of another kind with such excellent effect that their value was universally recognized, and all opposition to their use effectually silenced. In 1603 he succeeded

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The sole edition of Montesquieu which need be mentioned here is that of Edouard Laboulaye (7 vols., Paris, 1875-1879), the sole biography that of Louis Vian (Paris, second edition, 1879). From the latter the facts of the above notice are principally drawn. *The bibliography of Montesquieu's published works is not of any special interest, but in respect of anecdota he occupies a singular position.* There is known to exist at La Brède a great mass of MSS. materials for the *Esprit des Lois*, additional *Lettres Persanes*, essays and fragments of all kinds, diaries, letters, notebooks, and so forth. *The present possessors*, however, who represent Montesquieu, though not in the direct male line, have hitherto refused permission to examine these to all editors and critics, though the publication of some of them has been vaguely promised. At present they are chiefly known by a paper contributed nearly *half a century ago to the Transactions* of the Academy of Agen (1834). (G. SA.)

MONTEVERDE, Claudio (1568-1643), the inventor of the "free style" of musical composition, was born at Cremona in 1568; he was engaged at an early age as violist to the duke of Mantua, and studied composition with some success under Ingegneri, the duke's "maestro di capella," though without thoroughly mastering the difficulties of musical science. His knowledge of counterpoint was limited, and his ear imperfect, but he was a bold experimenter, and his undisguised empiricism led to discoveries which exercised a lasting influence upon the progress of art. He was the first composer who ventured to use unprepared dissonances,—employing them first in his madrigals, the beauty of which they utterly destroyed, but afterwards introducing them into music of another kind with such excellent effect that their value was universally recognized, and all opposition to their use effectually silenced. In 1603 he succeeded

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MONTEZUMA. See Cortes and Mexico.

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remarkable of which is Corndon Hill, rising to a height of 1700 feet. In some places the sedimentary rocks have been penetrated by trap mingled with shale or schist. Along the lines of dislocation there are frequent deposits of metallic lodes, carried there by the heated water rising from below. The lead mines of Montgomeryshire are of considerable importance, and at present the metal is wrought at seven different places. In 1881 the amount of lead ore obtained in the various mines was 3432 tons, yielding 2693 tons of lead and 25,432 oz. of silver, the total value being £36,495. There were also obtained 1114 tons of zinc ore, yielding 610 tons of zinc, of a total value of £3231.

Agriculture.—The climate is mild and genial, and the soil in the valleys remarkably fertile, especially along the banks of the Severn. A considerable portion on the borders of Merioneth is, however, occupied chiefly by heath and moss. The number of holdings has been rather decreasing of late years, the decrease being chiefly in those below 50 acres in extent, which in 1880 (the latest year regarding which there is information) numbered 3572, while there were 1650 between 50 and 300 acres, and 45 above 300 acres, of which 2 were above 1000. According to the agricultural returns of 1882, the total area of arable land was 256,081 acres, or nearly one-half of the whole. Of this 53,538 were under corn crops, 163,111 were permanent pasture, 23,882 rotation grasses, and only 11,107 green crops; 157 acres were under orchards, 2 under market gardens, 37 under nursery grounds, and 22,711 under woods. Of the corn crops, wheat occupied 18,665 acres, and oats 23,937 acres. Cattle, which are chiefly Herefords and cross-breeds, though there are some Devons and a few of the old Montgomeryshire breed, numbered 62,033 in 1882, of which 21,912 were cows and heifers in milk or in calf. Horses in 1882 numbered 13,985, of which 7060 were used solely for agricultural purposes. The county was long famous for its hardy breed of small horses called *merlins*, which are still to be met with. Many good hunters and cart-horses are now bred. The number of sheep in 1882 was 305,641. On some of the heath lands in the centre and west of the county a diminutive breed of sheep called *cluns* is pastured, but those kept in the better cultivated regions are principally Shropshire Downs. According to the latest return, the land was divided among 3241 proprietors, possessing 387,342 acres, with a gross annual rental of £378,512. Of these, 1311, or 40 per cent., possessed less than one acre, 32 possessed between 1000 and 2000 acres, and 25 between 2000 and 5000; the following possessed upwards of 5000 acres, viz.—Earl Powis, 33,545; Sir W. W. Wynn, 32,963; Lord Sudeley, 17,158; J. Naylor, 9275; and marquis of Londonderry, 7100.

Manufactures.—In all the towns the manufacture of woollen cloth, especially Welsh flannel, is carried on, and although the industry was lately on the decline it is now reviving.

Administration and Population.—Montgomeryshire comprises nine hundreds, and the municipal boroughs of Llanidloes (3421) and Welshpool (7107). Llanfyllin, Llanidloes, Machynlleth, Montgomery, Newtown, and Welshpool form the Montgomery district of boroughs, with a total population in 1881 of 19,925, and return one member to parliament. One member is also returned for the county. Montgomeryshire is partly in the dioceses of Bangor, Hereford, and St Asaph, and contains sixty-eight civil parishes, townships, or places, as well as parts of other parishes in adjoining counties. From 65,700 in 1831 the population had increased in 1851 to 67,335, and in 1871 to 67,623, but in 1881 it had diminished to 65,718, of whom 33,004 were males and 32,714 females.

History.—At the time of the Roman invasion, Montgomery was possessed by a tribe of the Cymri called Ordovices. Traces of several of the old British camps still remain, the principal being those at Doladdyn, on Breidden Hill, and at Caereinion. There are also a large number of cairns and barrows. The county was traversed by the great Roman road, the *Via Devana*, which was joined by a number of others; but the remains of Roman camps or stations are unimportant. After being vacated by the Romans, little is known of the history of Montgomery, until Wales was subdivided into three districts at the death of Rhodri the Great. Montgomery was then included under Powys, and formed the chief portion of Powys Gwenwynwyn, sometimes called Upper Powys. Powys or Powis Castle, the seat of the rulers of Upper Powys, was founded in 1108. Baldwyn, from which the county takes its Welsh name, was lieutenant of the marches; and, for the purpose of holding the district in check, a castle was built about the end of the 11th century, which, after being captured by the natives, was retaken by Roger de Montgomery. He gave his name to the castle, and to the surrounding district of ancient Powys, which was made a county by Henry VIII. in 1533.

MONTGOMERY, the county town, is situated on the declivity of a well-wooded hill near the eastern bank of the Severn, 21½ miles south by west of Shrewsbury, and 187¾ by rail north-west by north of London. It is a clean and well-built town, but somewhat scattered and irregular. The principal buildings are the parish church of Saint Nicholas (an old cruciform structure) and the town-hall. The borough has returned members to parliament since the time of Henry VIII., but by the Reform Act of 1832 it was constituted one of the Montgomery district of boroughs, which together return one member. The population of the borough (area, 3323 acres) was 1194 in 1881.

There are only a few crumbling remains of the old fortress of Montgomery, originally founded in the time of William the Conqueror to overawe the Welsh, and held by Roger de Montgomery, from whom the town takes its name. The castle was greatly enlarged in the time of Henry III., when it was the scene of frequent contests between that monarch and Llewelyn the Great. In the 14th century it was held by the Mortimers, from whom it passed to the house of York. By the crown it was granted in the 15th century to the Herberts of Cherbury, but during the Civil War it was surrendered by Lord Herbert of Cherbury to the Parliamentary forces, by whom it was dismantled.

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remarkable of which is Corndon Hill, rising to a height of 1700 feet. In some places the sedimentary rocks have been penetrated by trap mingled with shale or schist. Along the lines of dislocation there are frequent deposits of metallic lodes, carried there by the heated water rising from below. The lead mines of Montgomeryshire are of considerable importance, and at present the metal is wrought at seven different places. In 1881 the amount of lead ore obtained in the various mines was 3432 tons, yielding 2693 tons of lead and 25,432 oz. of silver, the total value being £36,495. There were also obtained 1114 tons of zinc ore, yielding 610 tons of zinc, of a total value of £3231.

Agriculture.—The climate is mild and genial, and the soil in the valleys remarkably fertile, especially along the banks of the Severn. A considerable portion on the borders of Merioneth is, however, occupied chiefly by heath and moss. The number of holdings has been rather decreasing of late years, the decrease being chiefly in those below 50 acres in extent, which in 1880 (the latest year regarding which there is information) numbered 3572, while there were 1650 between 50 and 300 acres, and 45 above 300 acres, of which 2 were above 1000. According to the agricultural returns of 1882, the total area of arable land was 256,081 acres, or nearly one-half of the whole. Of this 53,538 were under corn crops, 163,111 were permanent pasture, 23,882 rotation grasses, and only 11,107 green crops; 157 acres were under orchards, 2 under market gardens, 37 under nursery grounds, and 22,711 under woods. Of the corn crops, wheat occupied 18,665 acres, and oats 23,937 acres. Cattle, which are chiefly Herefords and cross-breeds, though there are some Devons and a few of the old Montgomeryshire breed, numbered 62,033 in 1882, of which 21,912 were cows and heifers in milk or in calf. Horses in 1882 numbered 13,985, of which 7060 were used solely for agricultural purposes. The county was long famous for its hardy breed of small horses called *merlins*, which are still to be met with. Many good hunters and cart-horses are now bred. The number of sheep in 1882 was 305,641. On some of the heath lands in the centre and west of the county a diminutive breed of sheep called *cluns* is pastured, but those kept in the better cultivated regions are principally Shropshire Downs. According to the latest return, the land was divided among 3241 proprietors, possessing 387,342 acres, with a gross annual rental of £378,512. Of these, 1311, or 40 per cent., possessed less than one acre, 32 possessed between 1000 and 2000 acres, and 25 between 2000 and 5000; the following possessed upwards of 5000 acres, viz.—Earl Powis, 33,545; Sir W. W. Wynn, 32,963; Lord Sudeley, 17,158; J. Naylor, 9275; and marquis of Londonderry, 7100.

Manufactures.—In all the towns the manufacture of woollen cloth, especially Welsh flannel, is carried on, and although the industry was lately on the decline it is now reviving.

Administration and Population.—Montgomeryshire comprises nine hundreds, and the municipal boroughs of Llanidloes (3421) and Welshpool (7107). Llanfyllin, Llanidloes, Machynlleth, Montgomery, Newtown, and Welshpool form the Montgomery district of boroughs, with a total population in 1881 of 19,925, and return one member to parliament. One member is also returned for the county. Montgomeryshire is partly in the dioceses of Bangor, Hereford, and St Asaph, and contains sixty-eight civil parishes, townships, or places, as well as parts of other parishes in adjoining counties. From 65,700 in 1831 the population had increased in 1851 to 67,335, and in 1871 to 67,623, but in 1881 it had diminished to 65,718, of whom 33,004 were males and 32,714 females.

History.—At the time of the Roman invasion, Montgomery was possessed by a tribe of the Cymri called Ordovices. Traces of several of the old British camps still remain, the principal being those at Dolarddyn, on Breidden Hill, and at Caereinion. There are also a large number of cairns and barrows. The county was traversed by the great Roman road, the *Via Devana*, which was joined by a number of others; but the remains of Roman camps or stations are unimportant. After being vacated by the Romans, little is known of the history of Montgomery, until Wales was subdivided into three districts at the death of Rhodri the Great. Montgomery was then included under Powys, and formed the chief portion of Powys Gwenwynwyn, sometimes called Upper Powys. Powys or Powis Castle, the seat of the rulers of Upper Powys, was founded in 1108. Baldwyn, from which the county takes its Welsh name, was lieutenant of the marches; and, for the purpose of holding the district in check, a castle was built about the end of the 11th century, which, after being captured by the natives, was retaken by Roger de Montgomery. He gave his name to the castle, and to the surrounding district of ancient Powys, which was made a county by Henry VIII. in 1533.

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of a mass of granite about 3000 feet in compass and 165 feet in height, rises at a distance of nearly a mile from the shore in the bay of St Michel, near the mouth of the Couësnon, at the vertex of the angle formed by the coasts of Brittany and Normandy. The quicksands by which it is surrounded, and which stretch far to seaward, are exposed at low water, and highly dangerous to those who venture on them without a guide. Recently efforts at reclamation have been made, and amongst other works a causeway has been constructed connecting Mont St Michel with the nearest point of the mainland (near Moidrey); an unfortunate consequence of these operations has been that some portions of the ramparts of the island have been sapped by the altered tidal currents. The fortress-abbey, to which the rock owes its fame, stands upon the more precipitous side towards the north and west; the sloping portion towards the east and south is occupied by dwelling-houses. The strong machicolated and turreted wall by which the whole is surrounded is pierced only by a single gateway. The northward wall of the abbey (La Merveille), dating from the 13th century, is of remarkable boldness; it is 246 feet in length and 108 feet in height, is supported by twenty buttresses, and is pierced by a variety of openings. The single street of the island, leading from the one gateway up to the donjon of the fortress, is lined with houses, most of them used as lodging-houses by visitors and pilgrims; it contains an old parish church, and the house of Du Guesclin is also pointed out. The abbey consists principally of two parallel buildings of three stories each, that on the east containing hospitium, refectory, and dormitory, and that on the west the cellar, knights' hall, and cloister. The knights' hall is a superb piece of Gothic architecture, measuring 85 feet by 59, with three rows of richly-ornamented pillars. The cloister is one of the purest and most graceful works of the 13th century (1228). The church has a number of imperfect turrets, and is surmounted by a square tower of the 17th century, with a statue of St Michael, which was crowned in 1877. The nave, which dates from the 11th century, is Norman; but the choir, which collapsed in 1421, has been rebuilt in the flamboyant style. Beneath is a fine crypt.

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MONTSERRAT, one of the Leeward Islands in the West Indies, situated 16° 45′ N. lat. and 62° 7′ W. long., is 12 miles long and 8 broad in its widest part, and has an area of 32 square miles. The uneven and rugged surface suggests possibly volcanic origin. Its general appearance is very picturesque, the most interesting natural feature being the Souffrière. The island was discovered by Columbus in 1493, and received its name either because of its broken appearance or after the mountain in Spain. It was colonized by the English under Sir Thomas Warner in 1632, and was taken by the French in 1664. Restored to the English in 1668, it capitulated to the French in 1782, but was again restored in 1784. It is now a presidency under the general government at Antigua, and has a legislative council, composed of officials and crown nominees. The climate is the most healthy in the West Indies. The population (10,087) consists principally of negroes, with several hundred whites. The revenue and expenditure average £5600 per annum. Sugar exports range from 1200 to occasionally 2000 tons. An important industry is the cultivation of limes and the manufacture of juice. About 700 puncheons of raw lime juice, 300 hogsheads of concentrated juice, and an increasing quantity of fresh green limes are exported annually. For the three years ending 1880 the average value of imports was £26,390, of exports £32,963. The principal town is Plymouth, lying midway along the south-west coast.

MONTSERRAT. Thirty miles to the north-west of Barcelona in Spain there rises a very remarkable mountain of grey conglomerate, 24 miles in circumference, and at its loftiest point (San Geronimo) a little more than 4000 feet in height. From the comparative lowness of the surrounding district, and from its extraordinary configuration, it is a conspicuous object for many miles around. The mountain consists of jagged pinnacles and spires rising abruptly from the base of the mass, which is cloven with many clefts, and abounds with steep precipices. It is the *Mons Serratus* of the Romans, the *Monte Serrado* of the Spaniards, and is thus named either in allusion to its jagged appearance, like the teeth of a saw, or because the eastern face is split, as if sawn,—which occurred, say the Spanish legends, at the time of the crucifixion, when the rocks were rent. The arms of the monastery represent a mountain with a saw resting upon it and penetrating some distance into its mass. Its pinnacles and pyramids and sharp angular masses resemble a mountain of hard crystalline volcanic tuff which occurs between Akureyri and Kalmanstunga in Iceland. The effect of Montserrat may be realized faintly if we place ourselves upon the roof of Milan cathedral, and imagine the forest of spires magnified a thousandfold. The central spire will represent San Geronimo. The result of this varied contour in the case of Montserrat is to make it one of the most picturesque places in Europe. Paths wind along the faces of the precipices, ascending to bare grey summits, descending to sheltered valleys filled with evergreens and flowers. The Pyrenees are seen in one direction, the sea in another, while the Llobregat winds at the foot of the mountain through the village of Monistrol. Manresa and other villages are seen scattered over the plain; and hills covered with a warm red soil alternate with rich valleys. Street says of Montserrat,—"After much experience of mountains, it strikes me more each time that I see it as among the very noblest of rocks."

The monastery, a great pile of buildings, stands upon a narrow platform on the edge of a vast chasm in the eastern face of the mountain. It owes its existence to an image of the Virgin, said to have been carved by St Luke, and brought to Barcelona by St Peter in 50 A.D. When the Moors invaded the province in 717, the image was taken to Montserrat and hidden in a cave. In 880 Gondemar, bishop of Vich, was attracted to the cave by sweet sounds and smells, and there found the image, which he determined to take to Manresa. But at a certain spot on the mountain the image refused to proceed farther; there it was consequently deposited, and a chapel was erected to contain it. A stone cross near the walls of the monastery still marks the spot where the image refused to move. Round the chapel a nunnery was built, and in 976 this was enlarged

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1. *The Eccentricity of the Moon's Orbit.*—He found that the moon moved most rapidly near a certain point of its orbit, and most slowly near the opposite point. The law of this motion was such that the phenomena could be represented by supposing the motion to be actually circular and uniform, the apparent variations being explained by the hypothesis that the earth was not situated in the centre of the orbit, but was displaced by an amount about equal to one-twentieth of the radius of the orbit. Then, by a well-known law of kinematics, the angular motion round the earth would be most rapid at the point nearest the earth—that is, at *perigee*—and slowest at the point most distant from the earth—that is, at *apogee*. Thus the apogee and perigee became two definite points of the orbit, indicated by the variations in the angular motion of the moon.

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$aa' \cos A \sin A'$. But we have $\cos A \sin A' = \frac{1}{2} \sin (A'+A) + \frac{1}{2} \sin (A'-A)$. Hence the product XY will be of the form

$$XY = \tfrac{1}{2} aa' \sin(A'+A) + \tfrac{1}{2} aa' \sin(A'-A) + \tfrac{1}{2} ab' \sin(A+B'+), \text{\&c.},$$

which is another series of the same general form. Moreover, if we suppose the angles A, B, &c., to increase uniformly with the time—that is, to admit of expression in the form

$$A = \alpha + mt,\ A' = \alpha' + m't, \text{\&c}—$$

we shall have, by integrating,

$$2\int XY\,dt = -\frac{aa'}{m+m'} \cos (A'+A) - \frac{aa'}{m'-m} \cos (A'-A), \text{\&c.},$$

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$aa' \cos A \sin A'$. But we have $\cos A \sin A' = \frac{1}{2} \sin (A'+A) + \frac{1}{2} \sin (A'-A)$. Hence the product XY will be of the form

$$XY = \tfrac{1}{2} aa' \sin (A'+A) + \tfrac{1}{2} aa' \sin (A'-A) + \tfrac{1}{2} ab' \sin (A+B'+), \text{\&c.},$$

which is another series of the same general form. Moreover, if we suppose the angles A, B, &c., to increase uniformly with the time—that is, to admit of expression in the form

$$A = \alpha + mt,\ A' = \alpha' + m't, \text{ \&c}—$$

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manca, where he waited to see what would happen. He heard that a subsidiary force under Sir David Baird had arrived at Corunna, and ordered it up to join him. At Salamanca he remained a whole month watching the triumphant successes of Napoleon and his lieutenants, and learning how little Spanish reports or Spanish valour were to be relied on. Though irritated by the menaces and abuse of Frere, the English minister to the junta, he waited till the 13th December, hearing daily of Spanish defeats, and then he determined to draw off upon his own small force the weight of Napoleon's power, and thus give Andalucia the winter in which to organize an army and prepare for another Baylen. With this intention he advanced through Toro and Mayorga, where Baird joined him, to Sahagun. He judged rightly that Napoleon would never advance into Andalucia and leave the English behind him, but that he would turn all his power against them. Having once drawn Napoleon's attention to himself, he began his famous retreat and fell back quickly, fighting every day and invariably with success. He now could test the military spirit he had taught at Shorncliffe, for the reserve under Sir Edward Paget consisted entirely of his own light regiments. To detail each step of the retreat and every skirmish would be but to rewrite Napier; suffice it to say that, with great loss of life and material, Moore reached Corunna on 12th January 1809. But the fleet to take the army home was not there; and the English would have to fight Soult, whose army was even more weakened and demoralized than Moore's, before they could embark. It was on 16th January that Moore fought his last battle; he fell early in the day, and knew at once that his wound was mortal. His last hours were cheered with the knowledge of victory, but were spent in recommending his old friends, such as Graham and Colborne, to the notice of the Government. Sir H. Hardinge's description of these hours is in its way inimitable, and in it must be studied how a modern Bayard should die in battle, every thought being for others, none for himself.

It may be possible in the face of his heroic death to exaggerate Moore's actual military services, but his influence on the British army cannot be overrated. The true military spirit of discipline and of valour, both in officers and men, had become nearly extinct during the American war. Abercromby, who looked back to the traditions of Minden, was the first to attempt to revive it, and his work was carried on by Moore. The formation of the light regiments at Shorncliffe was the answer to the new French tactics, and it was left to Wellington to show the success of the experiment. Moore's powers as a statesman are shown in his despatches written at Salamanca, and he had the truest gift of a great man, that of judging men. It may be noticed that, while Wellington perpetually grumbled at the bad qualities of his officers and formed no school, Moore's name is associated with the career of all who made their mark. Among generals, Hope, Graham, Sir E. Paget, Hill, and Craufurd, all felt and submitted to his ascendency, and of younger officers it was ever the proud boast of the Napiers, Colborne, the Beckwiths, and Barnard that they were the pupils of Moore, not of Wellington. Nay more, he inspired an historian. The description of Moore's retreat in Napier is perhaps the finest piece of military history in the English language, not only because the author was present, but because his heart was with the leader of that retreat; and, if Napier felt towards Wellington as the soldiers of the tenth legion felt towards Cæsar, he felt towards Moore the personal love and devotion of a cavalier towards Montrose.

The great authority for Moore's life is the *Life of Sir John Moore*, by his brother, J. C. Moore (1833); see also *Narrative of the Campaign of Sir John Moore in Spain*, by his brother, J. C. Moore (4to, with plans, 1809); Napier, *Peninsular War*, Bk. iv., and his *Life of Sir Charles Napier*. For views adverse to Moore's retreat, see Charmilly, *Narrative* (1810), and Sir Bartle Frere, *Life of the Rt. Hon. J. H. Frere* (published in vol. i. of his works). Consult also Wilson, *Campaign in Egypt*, for Moore's services there, and the *Life of Gilbert Elliot, First Lord Minto*, for the squabble in Corsica. (H. M. S.)

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The fragment of autobiography in which Moore draws a softly-coloured picture of his early life in Dublin lets us into the secret of the seeming miracle of his social conquest. Externals apart, the spirit of his social surroundings in Little Aungier Street had much in common with the society to which he was introduced in London. He was born in the proscribed sect of Catholics, whose exclusion from the society of the Castle produced a closer union among their various ranks, and thus, from the first, Moore was no stranger to the more refined gaieties of social intercourse. It was, upon the whole, a gay life in Catholic society, though the conspiracy of the United Irishmen was being quietly formed beneath the surface. Amateur theatricals was one of their favourite diversions, and gifts of reciting and singing were not likely to die for want of applause. Moore's schoolmaster was a leader in these entertainments, a writer of prologues and epilogues and incidental songs; and at a very early age Master Thomas Moore was one of his show-boys, ardently encouraged in all his exercises by a very affectionate mother at home. Before he left school he had acquired fame in his own circle as a song-writer, and had published, in the *Anthologia Hibernica*, verses "to Zelia on her charging the author with writing too much on love." This was in 1793. In that year the prohibition against Catholics entering Trinity College was removed, and next year Moore took advantage of the new freedom. As one of the first Catholic entrants, he had an exceptional stimulus to work, and there industriously acquired that classical scholarship with which he won the hearts of such learned Whigs as Lansdowne and Holland, while he charmed fashionable ladies with the grace of his songs. Young Moore's social atmosphere was, of course, strongly charged with patriotism and hatred of the excesses of

manca, where he waited to see what would happen. He heard that a subsidiary force under Sir David Baird had arrived at Corunna, and ordered it up to join him. At Salamanca he remained a whole month watching the triumphant successes of Napoleon and his lieutenants, and learning how little Spanish reports or Spanish valour were to be relied on. Though irritated by the menaces and abuse of Frere, the English minister to the junta, he waited till the 13th December, hearing daily of Spanish defeats, and then he determined to draw off upon his own small force the weight of Napoleon's power, and thus give Andalucia the winter in which to organize an army and prepare for another Baylen. With this intention he advanced through Toro and Mayorga, where Baird joined him, to Sahagun. He judged rightly that Napoleon would never advance into Andalucia and leave the English behind him, but that he would turn all his power against them. Having once drawn Napoleon's attention to himself, he began his famous retreat and fell back quickly, fighting every day and invariably with success. He now could test the military spirit he had taught at Shorncliffe, for the reserve under Sir Edward Paget consisted entirely of his own light regiments. To detail each step of the retreat and every skirmish would be but to rewrite Napier; suffice it to say that, with great loss of life and material, Moore reached Corunna on 12th January 1809. But the fleet to take the army home was not there; and the English would have to fight Soult, whose army was even more weakened and demoralized than Moore's, before they could embark. It was on 16th January that Moore fought his last battle; he fell early in the day, and knew at once that his wound was mortal. His last hours were cheered with the knowledge of victory, but were spent in recommending his old friends, such as Graham and Colborne, to the notice of the Government. Sir H. Hardinge's description of these hours is in its way inimitable, and in it must be studied how a modern Bayard should die in battle, every thought being for others, none for himself.

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The regent's desertion of the Whigs in 1812 cut them off from all hope of office for many years to come, and Moore from his last hope of a snug sinecure, when Lord Moira also was practically "oblivious" of him. There was at once a marked increase in his literary fertility, and he broke ground in a new field, which he cultivated with pre-eminent success—political squib-writing. Moore was incapable of anything like rancour, but he felt the disappointment of his hopes enough to quicken his fancy and sharpen the edge of his wit. The prince regent, his old friend and patron, who was said to have begged all Lord Moira's appointments for personal favourites, was his first butt. The prince's defects and foibles, his fatness, his huge whiskers, his love for cutlets and curaçoa, for aged mistresses and practical jokes, were ridiculed with the lightest of clever hands. Moore opened fire in the *Morning Chronicle*, and crowned his success next year (1813) with a thin volume of "Intercepted Letters," *The Twopenny Post Bag*. A very little knowledge of the gossip of the time enables us to understand the delight with which Moore's sallies were received in the year which witnessed the imprisonment of Leigh Hunt for more outspoken attacks on the regent. Moore received every encouragement to work the new vein. He was at one time in receipt of a regular salary from the *Times*; and his little volumes of squibs published at intervals,—*The Fudge Family in Paris*, 1818; *The Journal of a Member of the Pococurante Society*, 1820; *Fables for the Holy Alliance*, 1823; *Odes on Cash, Corn, Catholics, and other Matters*, 1828; *The Fudges in England*, 1835—went through many editions. The prose *Memoirs of Captain Rock* (1824) may be added to the list. Moore's only failure was *Tom Cribb's Memorial to Congress* (1819), for which he had made an elaborate study of thieves' slang. It was of course on the side of the Whigs that Moore employed his pen, and his favourite topics were the system of repression in Ireland and the disabilities of the Catholics. He made rather too serious a claim for his pasquinades when he spoke of "laying the lash on the back of the bigot and the oppressor." It was not exactly a lash or a scourge that he wielded. It was in happy, airily malicious ridicule of personal foibles that his strength lay; he pricked and teased his victims with sharp and tiny arrows. But, light as his hand was, he was fairly entitled to the enthusiastic gratitude of his countrymen for his share in effecting Catholic emancipation.

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of the group; and their beauty is enhanced by their scarlet bill and legs. Two, *P. alleni* of the Ethiopian Region and the South-American *P. parva*, are of small size. Of the larger species, *P. cæruleus* is the "Porphyrio" of the ancients, and inhabits certain localities on both sides of the Mediterranean, while the rest are widely dispersed within the tropics, and even beyond them, as in Australia and New Zealand. But this last country has produced a more exaggerated form, *Notornis*, which has an interesting and perhaps unique history. First described from a fossil skull by Prof. Owen,[1] and then thought to be extinct, an example was soon after taken alive,[2] the skin of which (with that of another procured like the first by Mr Walter Mantell) may be seen in the British Museum. Other fossil remains were from time to time noted by Prof. Owen[3]; but it began to be feared that the bird had ceased to exist,[4] until a third example was taken about the year 1879, the skin and most of the bones of which, after undergoing examination in New Zealand by Dr Buller and Prof. T. J. Parker,[5] found their way to the museum of Dresden, where Dr A. B. Meyer discovered the recent remains to be specifically distinct from the fossil, and while keeping for the latter the name *N. mantelli* gives the former that of *N. hochstetteri*. What seems to have been a third species of *Notornis* formerly inhabited Lord Howe's Island, but is now extinct (see BIRDS, vol. iii. p. 732, note). Whether the genus *Aptornis*, of which Prof. Owen has described the remains from New Zealand, was most nearly allied to *Notornis* and *Porphyrio* cannot here be decided. Prof. T. J. Parker (*loc. cit.*) considers it a "development by degeneration of an ocydromine type" (see OCYDROME). (A. N.)

MOOSE. See DEER, vol. vii. p. 24.

MORADABAD. See MURADABAD.

MORAL PHILOSOPHY. See ETHICS, vol. viii. p. 574.

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of the group; and their beauty is enhanced by their scarlet bill and legs. Two, *P. alleni* of the Ethiopian Region and the South-American *P. parva*, are of small size. Of the larger species, *P. cæruleus* is the "Porphyrio" of the ancients, and inhabits certain localities on both sides of the Mediterranean, while the rest are widely dispersed within the tropics, and even beyond them, as in Australia and New Zealand. But this last country has produced a more exaggerated form, *Notornis*, which has an interesting and perhaps unique history. First described from a fossil skull by Prof. Owen,[1] and then thought to be extinct, an example was soon after taken alive,[2] the skin of which (with that of another procured like the first by Mr Walter Mantell) may be seen in the British Museum. Other fossil remains were from time to time noted by Prof. Owen[3]; but it began to be feared that the bird had ceased to exist,[4] until a third example was taken about the year 1879, the skin and most of the bones of which, after undergoing examination in New Zealand by Dr Buller and Prof. T. J. Parker,[5] found their way to the museum of Dresden, where Dr A. B. Meyer discovered the recent remains to be specifically distinct from the fossil, and while keeping for the latter the name *N. mantelli* gives the former that of *N. hochstetteri*. What seems to have been a third species of *Notornis* formerly inhabited Lord Howe's Island, but is now extinct (see BIRDS, vol. iii. p. 732, note). Whether the genus *Aptornis*, of which Prof. Owen has described the remains from New Zealand, was most nearly allied to *Notornis* and *Porphyrio* cannot here be decided. Prof. T. J. Parker (*loc. cit.*) considers it a "development by degeneration of an ocydromine type" (see OCYDROME). (A. N.)

MOOSE. See DEER, vol. vii. p. 24.

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MORE, THOMAS (1478-1535), lord chancellor, and one of the most illustrious Englishmen of his century, was born in Milk Street in the City of London, 7th February 1478. He received the rudiments of education at St Anthony's School in Threadneedle Street, at that time under Nicolas Holt held to be the best in the city. He was early placed in the household of Cardinal Morton, archbishop of Canterbury. Admission to the cardinal's family was esteemed a high privilege, and was sought as a school of manners and as an introduction to the world by the sons of the best families in the kingdom. Young Thomas More obtained admission through the influence of his father, Sir Thomas, then a rising barrister and afterwards a justice of the Court of King's Bench. The usual prognostication of future distinction is attributed in the case of More to Cardinal Morton, "who would often tell the nobles sitting at table with him, where young Thomas waited on him, whosoever liveth to trie it shall see this

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MORE, THOMAS (1478-1535), lord chancellor, and one of the most illustrious Englishmen of his century, was born in Milk Street in the City of London, 7th February 1478. He received the rudiments of education at St Anthony's School in Threadneedle Street, at that time under Nicolas Holt held to be the best in the city. He was early placed in the household of Cardinal Morton, archbishop of Canterbury. Admission to the cardinal's family was esteemed a high privilege, and was sought as a school of manners and as an introduction to the world by the sons of the best families in the kingdom. Young Thomas More obtained admission through the influence of his father, Sir Thomas, then a rising barrister and afterwards a justice of the Court of King's Bench. The usual prognostication of future distinction is attributed in the case of More to Cardinal Morton, "who would often tell the nobles sitting at table with him, where young Thomas waited on him, whosoever liveth to trie it shall see this

[1] "Prefatio Generalissima" prefixed to his *Opera Omnia*, 1679.

[2] The place and its religious marvels are glanced at in the romance of *John Inglesant* (chap. xv.).

More's father, whom upon some pretext he threw into the Tower, and he only released him upon payment of a fine of £100. Thomas More even found it advisable to withdraw from public life into obscurity. During this period of retirement the old dilemma recurred. One while he devoted himself to the sciences, "perfecting himself in music, arithmetic, geometry, and astronomy, learning the French tongue, and recreating his tired spirits on the viol,"[1] or translating epigrams from the Greek anthology; another while resolving to take priest's orders.

From dreams of clerical celibacy he was roused by making acquaintance with the family of John Colt of New Hall, in Essex. The "honest and sweet conversation" of the daughters attracted him, and though his inclination led him to prefer the second he married the eldest, not liking to put the affront upon her of passing her over in favour of her younger sister. The death of the old king in 1507 restored him to the practice of his profession, and to that public career for which his abilities specially fitted him. From this time there was scarce a cause of importance in which he was not engaged. His professional income amounted to £400 a year, equal to £4000 in present money, and, "considering the relative profits of the law and the value of money, probably indicated as high a station as £10,000 at the present day" (Campbell). It was not long before he attracted the attention of the young king and of Wolsey. The Latin verses which he presented to Henry on the occasion of his coronation did not deserve particular notice amid the crowd of congratulatory odes. But the spirit with which he pleaded before the Star Chamber in a case of the Crown *v.* the Pope recommended him to the royal favour, and marked him out for employment. More obtained in this case judgment against the crown. Henry, who was present in person at the trial, had the good sense not to resent the defeat, but took the counsel to whose advocacy it was due into his service. In 1514 More was made master of the requests, knighted, and sworn a member of the privy council. He was repeatedly employed on embassies to the Low Countries, and was for a long time stationed at Calais as agent in the shifty negotiations carried on by Wolsey with the court of France. In 1519 he was compelled to resign his post of undersheriff to the city and his private practice at the bar. In 1521 he was appointed treasurer of the exchequer, and in the parliament of 1523 he was elected speaker. The choice of this officer rested nominally with the House itself, but in practice was always dictated by the court. Sir Thomas More was pitched upon by the court on this occasion in order that his popularity with the Commons might be employed to carry the money grant for which Wolsey asked. To the great disappointment of the court More remained firm to the popular cause, and it was greatly owing to his influence that its demands were resisted. From this occurrence may be dated the jealousy which the cardinal began to exhibit towards More. Wolsey made an attempt to get him out of the way by sending him as ambassador to Spain. More defeated the design by a personal appeal to the king, alleging that the climate would be fatal to his health. Henry, who saw through the artifice, and was already looking round for a more popular successor to Wolsey, made the gracious answer that he would employ More otherwise. In 1525 More was appointed chancellor of the duchy of Lancaster, and no pains were spared to attach him to the court. The king frequently sent for him into his closet, and discoursed with him on astronomy, geometry, and points of divinity. This growing favour, by which many men would have been carried away, did not impose upon More. He discouraged the king's advances, showed reluctance to go to the palace, and seemed constrained when there. Then the king began to come himself to More's house at Chelsea, and would dine with him without previous notice. Roper mentions one of these visits, when the king after dinner walked in the garden by the space of an hour, holding his arm round More's neck. Roper afterwards congratulated his father-in-law on the distinguished honour which had been shown him. "I thank our Lord," was the reply, "I find his grace my very good lord indeed; and I believe he doth as singularly favour me as any subject within this realm. Howbeit, son Roper, I may tell thee I have no cause to be proud thereof, for if my head would win him a castle in France, it should not fail to go." As a last resource More tried the expedient of silence, dissembling his wit and affecting to be dull. This had the desired effect so far that he was less often sent for. But it did not alter the royal policy, and in 1529, when a successo had to be found for Wolsey, More was raised to the chancellorship. The selection was justified by More's high reputation, but it was also significant of the modification which the policy of the court was then undergoing. It was a concession to the rising popular party, to which it was supposed that More's politics inclined him. The public favour with which his appointment had been received was justified by his conduct as judge in the Court of Chancery. Having heard causes in the forenoon between eight and eleven, after dinner he sat again to receive petitions. The meaner the suppliant was th more affably he would speak to him, and the more speedi'y he would despatch his case. In this respect he formed a great contrast to his predecessor, whose arrears he soon cleared off. One morning being told by the officer th there was not another cause before the court, he ordere the fact to be entered on record, as it had never happene before. 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Stapleton (*Tres Thomæ, s. res gestæ S. Thomæ apostoli, S. Thomæ archiepiscopi Cantuariensis, Thomæ Mori*, Douay, 1588, Cologne, 1612, and the *Vita Thomæ Mori* (separately), Gratz, 1689) translates Roper, interweaving what material he could find scattered through More's works and letters and the notices of him in the writings of his contemporaries. Cresacre More, great-grandson of Sir Thomas, compiled a new life about the year 1627. It was printed without date, but, according to the editor, Hunter, in 1631. The title of this edition is—*The Life of Sir Thos. More, Lord High Chancellour of England*, 4to, s. l. et a., and with new title-page, 1642, 1726, 1828. This life is cited by the subsequent biographers as an independent authority. But it is almost entirely borrowed from Roper and Stapleton. The additions made have sometimes the appearance of rhetorical amplifications of Roper's simple statements. At other times they are decorative miracles. The whole is couched in that strain of devotional exaggeration in which the lives of the saints are usually composed. The author seems to imply that he had received supernatural communications from the spirit of his ancestor. Already, only eighty years after More's execution, hagiography had taken possession of the facts, and was transmuting them into an edifying legend. Cresacre More's *Life* cannot be alleged as evidence for any facts which are not otherwise vouched. It has been remarked by Hunter that More's life and works have been all along manipulated for political purposes, and in the interest of the holy see. In Mary's reign, and in the tide of Catholic reaction, Roper and Harpsfield wrote lives of him; Ellis Heywood dedicated his *Il Moro* to Cardinal Pole, and Tottell reprinted the folio of his English works. Stapleton prepared his *Tres Thomæ* in 1588, when the recovery of England to the see of Rome was looked for by the Spanish invasion. In 1599, when there was a prospect of a disputed succession, the anonymous *Life* by B. R. was composed; and soon after Charles had allied himself with a Catholic, the *Life* by Cresacre More issued from the press. Hunter might have added that Stapleton was being reprinted at Gratz at the time when the conversion of England was expected from James II. The later lives of Sir Thomas More have been numerous, but the only one which has any critical value is that by G. T. Rudhart *Thomas Morus, aus den Quellen bearbeitet*, Nuremberg, 1829. Other lives are by J. Hoddesdon, London, 1652, 1662; by Cayley, 2 vols., London, 1808; by Mackintosh, *Lardner's Cab. Cyclop.*, London, 1831, 1844; and in More's *Works*, London, 1845; by Lord Campbell in *Lives of the Chancellors*, vol. i., 1848-50; by D. Nisard in *Renaissance et Réforme*; by Baumstark, Freiburg, 1879. A biographical study on More's Latin poems is *Philomorus* by J. H. Marsden, 2d ed., London, 1878.

More's writings are numerous, and a complete bibliography of them would occupy several columns. His English *Works* were collected and published in one vol. folio by Rastall, London, 1530, and reprinted by Tottell, London, 1557. His Latin *Works* were also separately collected in one vol., Basel, 1563; Louvain, 1566; and, most complete, Frankfort and Leipsic, 1689. The *Utopia* has had numerous editions, the first is Louv., 1516. There are two English translations of the *Utopia*, by R. Robynson, London, 1551, 1556, 1624, and by Gilb. Burnet, 1688. The Latin poems, *Progymnasmata*, appeared in 1518, 1520, 1563. This last edition contains the *Utopia* and other prose Latin pieces. (M. P.)

MOREAU, HÉGÉSIPPE, a minor lyric poet of disputed but considerable talent, was born at Paris on the 9th April 1810, and died in the hospital of La Charité on the 10th December 1838. In his early youth his parents, who were very ill-off, migrated to Provins, where the mother went into service and the father took the post of usher in a public school. Both died in the same refuge for the destitute which afterwards received their son. Hégésippe was fairly educated and was apprenticed to a printer, but he preferred the work (in France usually paid most miserably) of "maître d'études" in a school. He went to Paris before 1830, and appears to have practised both his occupations there, though for the most part he either adopted by choice or was driven by ill-fortune to adopt the singular life of alternate hardship and cheap dissipation which is dignified in France by the name of Bohemianism. In Moreau's case there is no doubt that the hardships exceeded the dissipation. He was habitually houseless, and is said to have exposed himself to the dangers of a cholera hospital in the great epidemic of 1832 simply to obtain shelter and food. Then he revisited Provins and published a kind of satirical serial called *Diogène*. Some years of this life entirely ruined his health, and it was only just before his death that he succeeded in getting his collected poems published, selling the copyright for £4 sterling and eighty copies of the book. It was received not unfavourably, but, as has happened in other cases, the author's death, which happened soon in the circumstances mentioned, was required to excite an interest which was proportionately excessive. Moreau's work, like that of many other young poets, has a strong note of imitation, his model being especially Béranger; and his character, both moral and literary, is not improved by obvious affectation in political, religious, and social matters. But some of his poems, such as *La Voulzie* and the charming *La Fermière*, have great sweetness, and he had a faculty of writing both in prose and poetry which seems to show that with better fortune, or, to speak honestly, with more intelligence and more perseverance he might easily have saved himself from the miserable destitution which was his lot.

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Stapleton (*Tres Thomæ, s. res gestæ S. Thomæ apostoli, S. Thomæ archiepiscopi Cantuariensis, Thomæ Mori*, Douay, 1588, Cologne, 1612, and the *Vita Thomæ Mori* (separately), Gratz, 1689) translates Roper, interweaving what material he could find scattered through More's works and letters and the notices of him in the writings of his contemporaries. Cresacre More, great-grandson of Sir Thomas, compiled a new life about the year 1627. It was printed without date, but, according to the editor, Hunter, in 1631. The title of this edition is—*The Life of Sir Thos. More, Lord High Chancellour of England*, 4to, s. l. et a., and with new title-page, 1642, 1726, 1828. This life is cited by the subsequent biographers as an independent authority. But it is almost entirely borrowed from Roper and Stapleton. The additions made have sometimes the appearance of rhetorical amplifications of Roper's simple statements. At other times they are decorative miracles. The whole is couched in that strain of devotional exaggeration in which the lives of the saints are usually composed. The author seems to imply that he had received supernatural communications from the spirit of his ancestor. Already, only eighty years after More's execution, hagiography had taken possession of the facts, and was transmuting them into an edifying legend. Cresacre More's *Life* cannot be alleged as evidence for any facts which are not otherwise vouched. It has been remarked by Hunter that More's life and works have been all along manipulated for political purposes, and in the interest of the holy see. In Mary's reign, and in the tide of Catholic reaction, Roper and Harpsfield wrote lives of him; Ellis Heywood dedicated his *Il Moro* to Cardinal Pole, and Tottell reprinted the folio of his English works. Stapleton prepared his *Tres Thomæ* in 1588, when the recovery of England to the see of Rome was looked for by the Spanish invasion. In 1599, when there was a prospect of a disputed succession, the anonymous *Life* by B. R. was composed; and soon after Charles had allied himself with a Catholic, the *Life* by Cresacre More issued from the press. Hunter might have added that Stapleton was being reprinted at Gratz at the time when the conversion of England was expected from James II. The later lives of Sir Thomas More have been numerous, but the only one which has any critical value is that by G. T. Rudhart *Thomas Morus, aus den Quellen bearbeitet*, Nuremberg, 1829. Other lives are by J. Hoddesdon, London, 1652, 1662; by Cayley, 2 vols., London, 1808; by Mackintosh, *Lardner's Cab. Cyclop.*, London, 1831, 1844; and in More's *Works*, London, 1845; by Lord Campbell in *Lives of the Chancellors*, vol. i., 1848-50; by D. Nisard in *Renaissance et Réforme*; by Baumstark, Freiburg, 1879. A biographical study on More's Latin poems is *Philomorus* by J. H. Marsden, 2d ed., London, 1878.

More's writings are numerous, and a complete bibliography of them would occupy several columns. His English *Works* were collected and published in one vol. folio by Rastall, London, 1530, and reprinted by Tottell, London, 1557. His Latin *Works* were also separately collected in one vol., Basel, 1563; Louvain, 1566; and, most complete, Frankfort and Leipsic, 1689. The *Utopia* has had numerous editions, the first is Louv., 1516. There are two English translations of the *Utopia*, by R. Robynson, London, 1551, 1556, 1624, and by Gilb. Burnet, 1688. The Latin poems, *Progymnasmata*, appeared in 1518, 1520, 1563. This last edition contains the *Utopia* and other prose Latin pieces. (M. P.)

MOREAU, Hégésippe, a minor lyric poet of disputed but considerable talent, was born at Paris on the 9th April 1810, and died in the hospital of La Charité on the 10th December 1838. In his early youth his parents, who were very ill-off, migrated to Provins, where the mother went into service and the father took the post of usher in a public school. Both died in the same refuge for the destitute which afterwards received their son. Hégésippe was fairly educated and was apprenticed to a printer, but he preferred the work (in France usually paid most miserably) of "maître d'études" in a school. He went to Paris before 1830, and appears to have practised both his occupations there, though for the most part he either adopted by choice or was driven by ill-fortune to adopt the singular life of alternate hardship and cheap dissipation which is dignified in France by the name of Bohemianism. In Moreau's case there is no doubt that the hardships exceeded the dissipation. He was habitually houseless, and is said to have exposed himself to the dangers of a cholera hospital in the great epidemic of 1832 simply to obtain shelter and food. Then he revisited Provins and published a kind of satirical serial called *Diogène*. Some years of this life entirely ruined his health, and it was only just before his death that he succeeded in getting his collected poems published, selling the copyright for £4 sterling and eighty copies of the book. It was received not unfavourably, but, as has happened in other cases, the author's death, which happened soon in the circumstances mentioned, was required to excite an interest which was proportionately excessive. Moreau's work, like that of many other young poets, has a strong note of imitation, his model being especially Béranger; and his character, both moral and literary, is not improved by obvious affectation in political, religious, and social matters. But some of his poems, such as *La Voulzie* and the charming *La Fermière*, have great sweetness, and he had a faculty of writing both in prose and poetry which seems to show that with better fortune, or, to speak honestly, with more intelligence and more perseverance he might easily have saved himself from the miserable destitution which was his lot.

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enjoyed much repute in its day; Haller speaks of it as "an immortal work, which may in itself serve for a pathological library." Morgagni, in the preface to his own work, discusses the defects and merits of the *Sepulchretum*; it was largely a compilation of other men's cases, well and ill authenticated; it was prolix, often inaccurate and misleading from ignorance of the normal anatomy, and it was wanting in what would now be called objective impartiality,—a quality which was introduced as decisively into morbid anatomy by Morgagni as it had been introduced two centuries earlier into normal human anatomy by Vesalius. Morgagni has narrated the circumstances under which the *De Sedibus* took origin. Having finished his edition of Valsalva in 1740, he was taking a holiday in the country, spending much of his time in the company of a young friend who was curious in many branches of knowledge. The conversation turned upon the *Sepulchretum* of Bonet, and it was suggested to Morgagni by his dilettante friend that he should put on record his own observations. It was agreed that letters on the anatomy of diseased organs and parts should be written for the perusal of this favoured youth (whose name does not transpire); and they were continued from time to time until they numbered seventy. Those seventy letters constitute the *De Sedibus et Causis Morborum*, which was given to the world as a systematic treatise in 2 vols. folio, Venice, 1761, twenty years after the task of epistolary instruction was begun. The letters are arranged in five books, treating of the morbid conditions of the body *a capite ad calcem*. The five books are dedicated respectively to Trew, Bromfield, Senac, Schreiber, and Meckel, as representing the several learned societies of which Morgagni was a foreign member. The five books together contain, according to an enumeration by the present writer, the records of some 640 dissections. Some of these are given at great length, and with a precision of statement and exhaustiveness of detail hardly surpassed in the so-called "protocols" of the German pathological institutes of the present time; others, again, are fragments brought in to elucidate some question that had arisen. The symptoms during the course of the malady and other antecedent circumstances are always prefixed with more or less fulness, and discussed from the point of view of the conditions found after death. Subjects in all ranks of life, including several cardinals, figure in this remarkable gallery of the dead. Many of the cases are taken from Morgagni's early experiences at Bologna, and from the records of his teachers Valsalva and Albertini not elsewhere published. Those six hundred or more cases are selected and arranged with method and purpose, and they are often (and somewhat casually) made the occasion of a long excursus on general pathology and therapeutics. The range of Morgagni's scholarship, as evidenced by his references to early and contemporary literature, strikes one with astonishment. It has been contended that he was himself not free from prolixity, the besetting sin of the learned; and certainly the form and arrangement of his treatise are such as to make it difficult to use in the present day, notwithstanding that it is well indexed in the original edition, in that of Tissot (3 vols. 4to, Yverdun, 1779), and in more recent editions. It differs from modern treatises in so far as the symptoms determine the order and manner of presenting the anatomical facts. Although Morgagni was the first to understand and to demonstrate the absolute necessity of basing diagnosis, prognosis, and treatment on an exact and comprehensive knowledge of anatomical conditions, he made no attempt (like that of the Vienna school sixty years later) to exalt pathological anatomy into a science disconnected from clinical medicine and remote from practical needs. His orderliness of anatomical method (implying his skill with the scalpel), his precision, his exhaustiveness, and his freedom from bias are his essentially modern or scientific qualities; his scholarship and high consideration for classical and foreign work, his sense of practical ends (or his common sense), and the breadth of his intellectual horizon prove him to have lived before medical science had become largely technical or mechanical. It is clear that Morgagni's immense personal influence during his lifetime did not alone make his book famous; at a distance of two hundred years from his birth, and more than one hundred from his death, the opinion is unanimous that his treatise was the commencement of the era of steady or cumulative progress in pathology and in practical medicine. Symptoms from that time ceased to be made up into more or less conventional groups, each of which was a disease; on the other hand, they began to be viewed as "the cry of the suffering organs," and it now became possible to develop Sydenham's grand conception of a natural history of disease in a catholic or scientific spirit. Laennec's application of the stethoscope to detect the sounds given out in diseased states of the heart and lungs, and Bright's application of the test-tube and re-agents to reach the structural and functional conditions of the kidney through the state of the urine, were the direct results of Morgagni's endeavour to lay bare the seats and causes of disease by anatomy; and those two means of diagnosis are the daily and hourly resource of every modern practitioner. In more general terms, Morgagni's work substituted localization for generalization and precision for vagueness.

A biography of Morgagni by Mosca was published at Naples in 1768. His life may also be read in Fabroni's *Vitæ illustr. Italor.*, and a convenient abridgment of Fabroni's memoir will be found prefixed to Tissot's edition of the *De Sedibus*, &c. A collected edition of his works was published at Venice in five vols. folio in 1765. (C. C.)

MORGAN, SYDNEY OWENSON, LADY (1777?-1859), novelist and miscellaneous describer and critic, was one of the most vivid and hotly-discussed literary personages of her generation. She was the daughter of an Irish actor, but it was one of her whims to keep the year of her birth a secret; "once upon a time" on Christmas day was her answer to inquiries. She began her literary career with a precocious volume of poems. Her second venture, *St Clair* (1804), a novel of ill-judged marriage, ill-starred love, and impassioned nature-worship, in which the influence of Goethe and Rousseau was apparent, at once attracted attention. Another novel, *The Novice of St Dominick* (1806), was also praised for its qualities of copious imagination and description, though the critics were inclined to nibble at the writer's grammar. But the book which made her reputation and brought her name into warm controversy was *The Wild Irish Girl*, also published in 1806. In this she appeared as the ardent champion of her native country, a politician rather than a novelist, extolling the beauty of Irish scenery, the richness of the natural wealth of Ireland, the noble traditions of its early history, and sketching types of the various classes with direct reference to the misgovernment to which she traced their evil features. She followed this up with *Patriotic Sketches* and *Metrical Fragments* in 1807, fitting some Irish melodies with words ("Kate Kearney" among the number) in the same year in which Moore began a similar task. Miss Owenson's politics and the favour shown her by the Whig aristocracy probably prompted the savage attack made upon her next novel, *Ida, a Woman of Athens*, in the first number of the *Quarterly* (1809). From first to last her style was open to the reproach of being made up too much of quotations, and her grammar was not always correct; but exuberant humour, keen wit, and fertility in the invention of striking and romantic incidents carry any unbiassed reader easily over all minor faults of composition. Her great ambition was to draw vivid pictures of the mingled "mirth and misery, ferocity and fun," of the Irish under English rule, and she succeeded. Her novels suffer as stories from this political purpose; she drags in too many character-sketches, and, though they are always drawn with vivacity and sharp penetration, they are drawn with too much bias of romantic enthusiasm on the one side and satirical spite on the other. In 1812 she was married to Sir T. C. Morgan, but books still continued to flow from her facile pen. In 1814 she produced her best novel, *O'Donnel*, a decided advance on previous work. She published an elaborate study of *France* under the Bourbon restoration in 1817. This was attacked with outrageous fury in the *Quarterly*, the authoress being accused of Jacobinism, falsehood, licentiousness, and impiety. She took her revenge indirectly in the novel of *Florence Macarthy* (1818), in which a *Quarterly* reviewer, Con Crawley, is insulted with supreme feminine ingenuity. *Italy*, a companion work to her *France*, was published in 1821; Lord Byron bears testimony to the justness of its pictures of life. The results of Italian historical studies were given in her *Life and Times of Salvator Rosa* (1824). Then she turned again to Irish manners and politics with a matter-of-fact book on *Absenteeism* (1825), and a highly stirring and romantic novel, *The O'Briens and the O'Flahertys* (1827). *The Book of the Boudoir* (1829) consisted of miscellaneous reflexions and reminiscences. Under the ministry of Lord Grey Lady Morgan obtained a pension of £300. During the last thirty years of her long life she broke no new ground, but to the last she was an entertaining writer, and sent some sprightly verses to the *Athenæum*

enjoyed much repute in its day; Haller speaks of it as "an immortal work, which may in itself serve for a pathological library." Morgagni, in the preface to his own work, discusses the defects and merits of the *Sepulchretum*; it was largely a compilation of other men's cases, well and ill authenticated; it was prolix, often inaccurate and misleading from ignorance of the normal anatomy, and it was wanting in what would now be called objective impartiality,—a quality which was introduced as decisively into morbid anatomy by Morgagni as it had been introduced two centuries earlier into normal human anatomy by Vesalius. Morgagni has narrated the circumstances under which the *De Sedibus* took origin. Having finished his edition of Valsalva in 1740, he was taking a holiday in the country, spending much of his time in the company of a young friend who was curious in many branches of knowledge. The conversation turned upon the *Sepulchretum* of Bonet, and it was suggested to Morgagni by his dilettante friend that he should put on record his own observations. It was agreed that letters on the anatomy of diseased organs and parts should be written for the perusal of this favoured youth (whose name does not transpire); and they were continued from time to time until they numbered seventy. Those seventy letters constitute the *De Sedibus et Causis Morborum*, which was given to the world as a systematic treatise in 2 vols. folio, Venice, 1761, twenty years after the task of epistolary instruction was begun. The letters are arranged in five books, treating of the morbid conditions of the body *a capite ad calcem*. The five books are dedicated respectively to Trew, Bromfield, Senac, Schreiber, and Meckel, as representing the several learned societies of which Morgagni was a foreign member. The five books together contain, according to an enumeration by the present writer, the records of some 640 dissections. Some of these are given at great length, and with a precision of statement and exhaustiveness of detail hardly surpassed in the so-called "protocols" of the German pathological institutes of the present time; others, again, are fragments brought in to elucidate some question that had arisen. The symptoms during the course of the malady and other antecedent circumstances are always prefixed with more or less fulness, and discussed from the point of view of the conditions found after death. Subjects in all ranks of life, including several cardinals, figure in this remarkable gallery of the dead. Many of the cases are taken from Morgagni's early experiences at Bologna, and from the records of his teachers Valsalva and Albertini not elsewhere published. Those six hundred or more cases are selected and arranged with method and purpose, and they are often (and somewhat casually) made the occasion of a long excursus on general pathology and therapeutics. The range of Morgagni's scholarship, as evidenced by his references to early and contemporary literature, strikes one with astonishment. It has been contended that he was himself not free from prolixity, the besetting sin of the learned; and certainly the form and arrangement of his treatise are such as to make it difficult to use in the present day, notwithstanding that it is well indexed in the original edition, in that of Tissot (3 vols. 4to, Yverdun, 1779), and in more recent editions. It differs from modern treatises in so far as the symptoms determine the order and manner of presenting the anatomical facts. Although Morgagni was the first to understand and to demonstrate the absolute necessity of basing diagnosis, prognosis, and treatment on an exact and comprehensive knowledge of anatomical conditions, he made no attempt (like that of the Vienna school sixty years later) to exalt pathological anatomy into a science disconnected from clinical medicine and remote from practical needs. His orderliness of anatomical method (implying his skill with the scalpel), his precision, his exhaustiveness, and his freedom from bias are his essentially modern or scientific qualities; his scholarship and high consideration for classical and foreign work, his sense of practical ends (or his common sense), and the breadth of his intellectual horizon prove him to have lived before medical science had become largely technical or mechanical. It is clear that Morgagni's immense personal influence during his lifetime did not alone make his book famous; at a distance of two hundred years from his birth, and more than one hundred from his death, the opinion is unanimous that his treatise was the commencement of the era of steady or cumulative progress in pathology and in practical medicine. Symptoms from that time ceased to be made up into more or less conventional groups, each of which was a disease; on the other hand, they began to be viewed as "the cry of the suffering organs," and it now became possible to develop Sydenham's grand conception of a natural history of disease in a catholic or scientific spirit. Laennec's application of the stethoscope to detect the sounds given out in diseased states of the heart and lungs, and Bright's application of the test-tube and re-agents to reach the structural and functional conditions of the kidney through the state of the urine, were the direct results of Morgagni's endeavour to lay bare the seats and causes of disease by anatomy; and those two means of diagnosis are the daily and hourly resource of every modern practitioner. In more general terms, Morgagni's work substituted localization for generalization and precision for vagueness.

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June 1572 he returned to France, and had begun to enter upon a diplomatic career (his earliest extant "mémoire," laid by Coligny before Charles IX., had reference to the duty of France to support the Low Countries in their struggle for independence) when the St Bartholomew massacre, from which he escaped with difficulty, compelled him to take refuge across the Channel. There he rendered valuable services to William of Orange, and also to the duke of Alençon-Anjou, as a semi-official political agent. Returning to France at the instance of La Noue towards the end of 1573, he took part with various success in numerous military enterprises, and was made prisoner at Dormans in 1575 (10th October), but not having been recognized he got off for a small ransom. Shortly afterwards he married Charlotte Arbaleste at Sedan, and at her request wrote as a bridal present the *Discours de la Vie et de la Mort* (1576), which has been so often reprinted and translated. In 1577 Henry of Navarre made him a member of his council and sent him on a diplomatic mission to England, and during this visit, which lasted more than a year, he found time among his other pressing occupations to prepare for the press his *Traité de l'Église où l'on traite des principales questions qui ont été mues sur ce point en nostre temps* (1578), which at once became popular. From July 1578 till his return to France in 1582 he was chiefly in the Low Countries, engaged in public business, and during this interval he wrote and published a considerable work in apologetical theology (*Traité de la vérité de la religion chrétienne contre les Athées, Épicuriens, Payens, Juifs, etc.*, 1581). With the death of the duke of Anjou in 1584, by which Henry of Navarre was brought within sight of the throne of France, the period of Mornay's greatest political activity began; his importance in the Huguenot counsels was further increased in 1588 by the death of the prince of Condé, to whose influence he practically succeeded. In April 1589 he was rewarded for the reconciliation of the two Henries with the governorship of Saumur, and he took active part in many of the military operations that followed the assassination of Henry III. in the following August. He was present at the siege of Dieppe, fought by the side of Henry IV. at Ivry, and was one of the besiegers of Rouen in 1591-92, until sent on a mission to the court of Elizabeth. A crisis in his political career was marked by Henry's abjuration of Protestantism in July 1593, which gradually led to Mornay's withdrawal from the court. In this year it was that he founded the Protestant academy or university of Saumur, which had a distinguished history until its suppression by Louis XIV. in 1683. In 1598 he published a work on which he had long been engaged, entitled *De l'institution, usage, et doctrine du saint sacrement de l'Eucharistie en l'Église ancienne*. It having reached his ears that Cardinal Du Perron had alleged that of the (thousands of) citations in this controversial work he could point out five hundred that were falsified or misunderstood, he challenged his assailant to a public discussion. This was at last arranged for by the good offices of the king, and took place at Fontainebleau on 4th May 1600. Only nine passages were discussed, but in each case the decision, one is not surprised in the circumstances to learn, went against the Protestant. Mornay, from whom every indication of the particular passages to be impugned had been persistently withheld, was forced by supervening illness to withdraw. Only once again did he appear at court, in 1607. He continued, however, to give his party the benefit of his counsel and active support to the end of his long and busy life. His last work, entitled *Mystère d'iniquité, c'est à dire, l'histoire de la Papauté*, appeared in 1611. In 1618 he was chosen a deputy to represent the French Protestants at the synod of Dort. Prohibited by Louis XIII. from personally attending, he nevertheless contributed materially to the deliberations of that assembly by written communications. In 1621 he was deprived of his governorship; and his death took place at La Forêt-sur-Sèvre on 11th November 1623.

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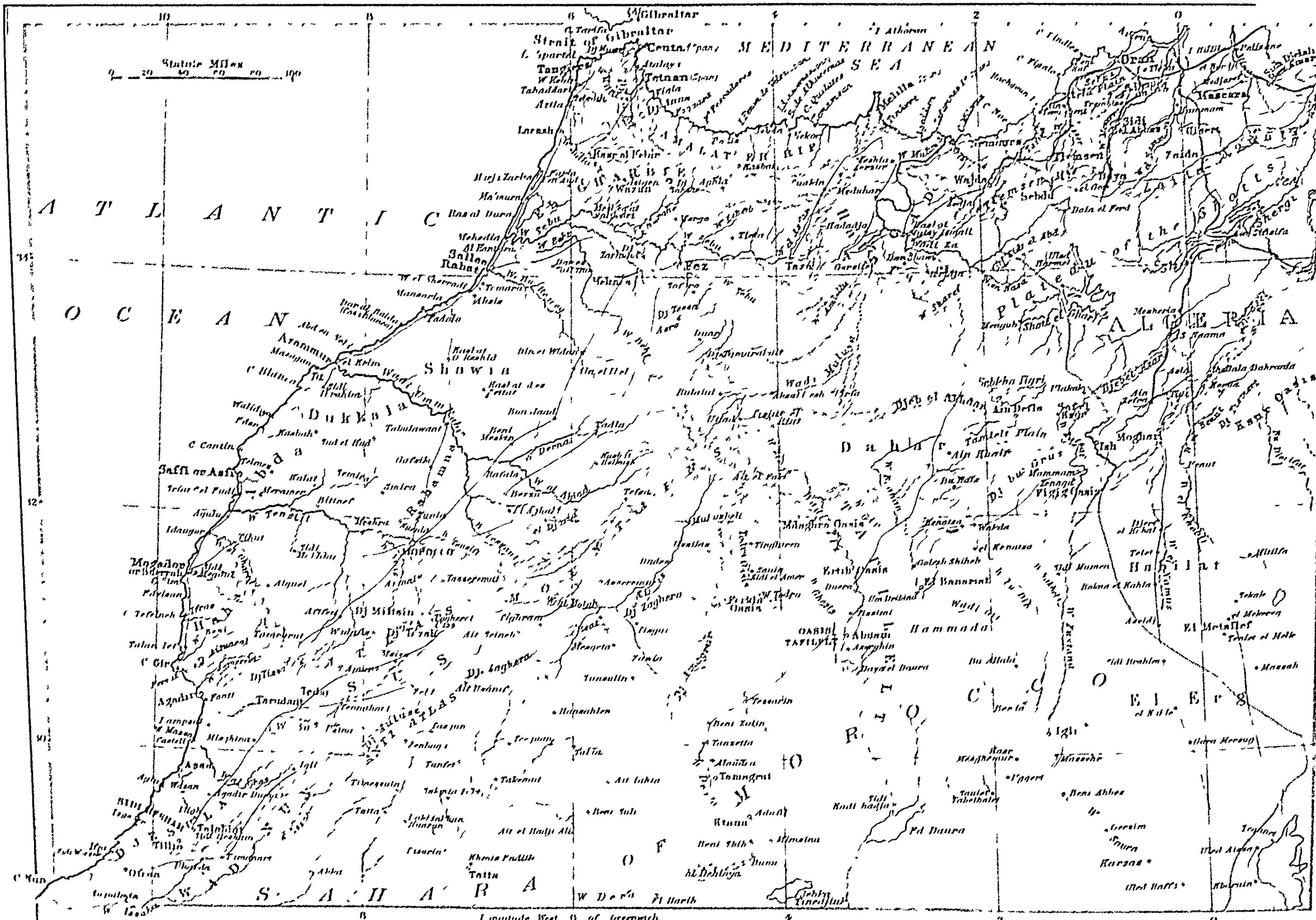
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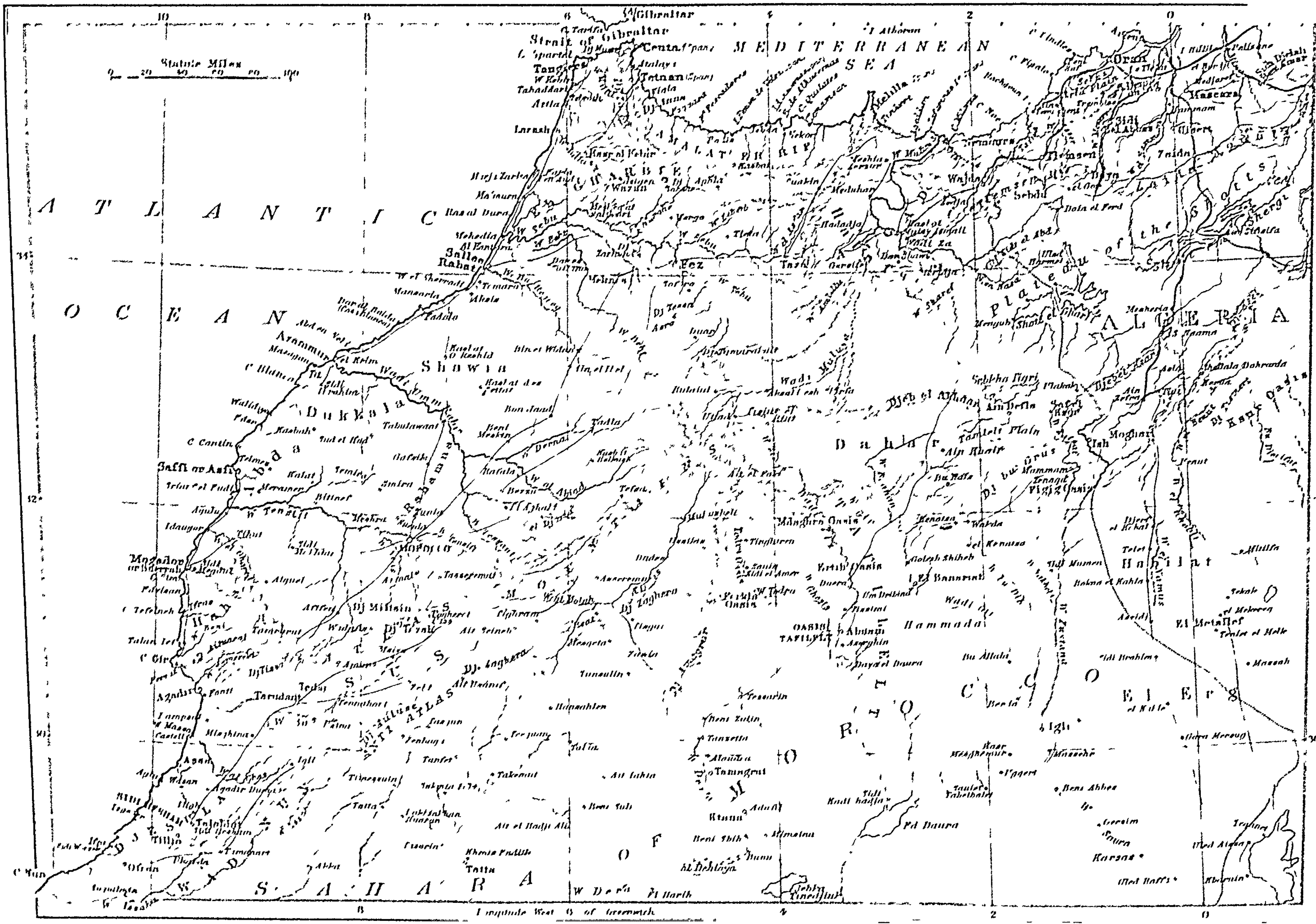
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Onward for 100 miles to Point Azammur and the mouth of the Umm Rabí' river a line of hills skirts the sea; the shore is for the most part low, and, with the exception of capes at Fadála (a small village) and Dár al-Baidá or Casa Blanca, it runs in a straight line west-south-west. Casa Blanca, the ancient Anfá, once a flourishing port, was ruined by the Portuguese (1468) in revenge for its piracies. It is now a place of 4000 inhabitants, and has a thriving export trade in maize, beans, and wool, and a European colony of about 100 persons. Azammur (that is, in Berber, "The Olives," viz., of the Sheikh Bú Shuaib), with 1000 inhabitants dependent on the shebbel fisheries in the river, stands on an eminence about 1½ miles from the sea on the south side of the Umm Rabí'. The bay of Mazagan (Mázíghan), a few miles to the south, curves westward with a boldness of sweep unusual on this coast. The town of Mazagan was founded by the Portuguese in 1506, and held by them till 1769.[2] About 8 miles to the south and less than a mile inland lie the extensive ruins of Tit, a town which proved a thorn in the side of the people of Mazagan till they sallied forth and destroyed it. At Cape Blanc (so called from its white cliffs) the coast, which bulged out at Cape Mazagan, again bends east to resume much the same general direction for 55 miles to Cape Cantin. On this stretch the only point of interest is Walidíya, formerly Al-Ghait; the excellent harbour praised by Edrisi is formed by an extensive lagoon, and M. Tissot thinks that by a little dredging the place would again become the safest shipping station on the whole Morocco seaboard.[3] Beyond Cape Cantin (300 feet high) the coast becomes bolder and more irregular, especially after the mouth of the Tensift is passed. About 18 miles farther lies Saffi (Asfi), "by far the most picturesque spot on the west coast," with the high walls and square towers of its Portuguese fortifications shown to advantage by the ruggedness of the site. South of MOGADOR (*q.v.*), and onwards beyond the limits of Morocco, the coast, becoming ever more and more inaccessible and dangerous in winter, is emphatically known as the Iron Coast. From Cape Sim or Ossim (Ras Tagriwalt), 10 miles south of Mogador, the direction is due south to Cape Gir (Igir Ufrani), the termination of Jebel Ida u Tanan (Rabbi Mardochée), the last spur of the Atlas proper. Rounding this headland we reach Agadir (Agadír 'n Igir), the Santa Cruz Major or Santa Cruz de Berberia of the Spaniards, formerly known as the Gate of the Soudan.[4] It is a little town with white battlements three-quarters of a mile in circumference, on a steep eminence 600 feet high. In the 15th century it was seized by the Portuguese, and Don Manuel caused it to be fortified; but in 1536 it was captured by Muley (Maulái) Ahmed al-Hasan. Its merchants were removed to Mogador in 1773. At the mouth of the Sús Leo places three little towns called Messa (Mássa), with a mosque popularly reputed the scene of Jonah's restoration to *terra firma*. The port of this name,[5] regularly visited by the Genoese traders in the 16th century, who exported skins, gum, wax, gold, and indigo, is no doubt at the mouth of the W. Mássa, 20 miles farther south.[6] Ifni, situated in 29° 23' N. lat., and Sidi Worzek, the Cape Non[7] of the Portuguese, are the only points calling for notice till the better known Cape Nun is reached, which lies 5 or 6 miles north of the W. Der'a. With the Der'a the Sahara may be said to begin.

On most maps the interior of Morocco is represented as extremely mountainous; but, while it is traversed from east to west by more than one strongly-defined range, the greater part of the surface is really occupied by undulating steppe-like tracts diversified by low hills. The backbone of the country is the Great Atlas (Daran of the Berbers).[8] At its western extremity the range averages from 4000 to 5000 feet in height; after a slight falling off for a few miles it rises till it attains an elevation of 10,000 feet; beyond the pass (about 60 miles from the sea) which leads from Morocco to Tárúdant the summits seem to be between 11,000 and 11,500 feet; about 40 miles farther east there is a second pass at an altitude of about 7000 feet; and beyond that the main ridge continues 30 miles at a height of about 12,000 feet, with a few peaks reaching to 13,000 or 13,500 feet. Snow lies on some of the summits as late

[1] The absurd story that about the 9th century it was an English possession has its root in the visits of the Normans to this quarter. The modern town sprang from a fortress built to protect the coast against them (Dozy, *Recherches*, 3d ed., ii. 264 *sq.*).

[2] The Portuguese settlers, who had to leave it when Don José decided on surrendering this last stronghold of his country in Morocco, were afterwards sent to Brazil, where they founded Villa Nova de Mazagan.

[3] *Bull. de la Soc. de Géogr.*, Paris, 1875.

[4] This must not be confounded with Santa Cruz de Mar Pequeña, a post established in 1476 somewhere on this coast by Herrera, lord of the Canary Islands, and in modern times the subject of much geographical disputation. After obtaining permission to reoccupy the site the Spanish Government was unable to identify it.

[5] See Valentin Ferdinand, *Beschreibung West Afrika's* (Mem. of the Acad. of Munich, 3d Class, pt. viii.).

[6] Ya'kúbi, *Descr. al-Maghribi*, p. 126; *Hist. des Berbères*, ii. 279.

[7] No, Non, Nor, Naum, Não, are among the various readings. It was another Cape Non to the south of Cape Bojador which seems to have given rise to the proverb, *Quem pasar o cabo de Não ou tornara ou não*. See *Bol. de la Soc. Geogr.*, p. 316, Madrid, 1880.

[8] Pliny says the natives called the Atlas "Dyrin."

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Onward for 100 miles to Point Azammur and the mouth of the Umm Rabí' river a line of hills skirts the sea; the shore is for the most part low, and, with the exception of capes at Fadála (a small village) and Dár al-Baidá or Casa Blanca, it runs in a straight line west-south-west. Casa Blanca, the ancient Anfá, once a flourishing port, was ruined by the Portuguese (1468) in revenge for its piracies. It is now a place of 4000 inhabitants, and has a thriving export trade in maize, beans, and wool, and a European colony of about 100 persons. Azammur (that is, in Berber, "The Olives," viz., of the Sheikh Bú Shuaib), with 1000 inhabitants dependent on the shebbel fisheries in the river, stands on an eminence about 1½ miles from the sea on the south side of the Umm Rabí'. The bay of Mazagan (Mázighan), a few miles to the south, curves westward with a boldness of sweep unusual on this coast. 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About 18 miles farther lies Saffi (Asfi), "by far the most picturesque spot on the west coast," with the high walls and square towers of its Portuguese fortifications shown to advantage by the ruggedness of the site. South of Mogador (*q.v.*), and onwards beyond the limits of Morocco, the coast, becoming ever more and more inaccessible and dangerous in winter, is emphatically known as the Iron Coast. From Cape Sim or Ossim (Ras Tagriwalt), 10 miles south of Mogador, the direction is due south to Cape Gir (Igir Ufrani), the termination of Jebel Ida u Tanan (Rabbi Mardochée), the last spur of the Atlas proper. Rounding this headland we reach Agadír (Agadír 'n Igir), the Santa Cruz Major or Santa Cruz de Berberia of the Spaniards, formerly known as the Gate of the Soudan.[4] It is a little town with white battlements three-quarters of a mile in circumference, on a steep eminence 600 feet high. In the 15th century it was seized by the Portuguese, and Don Manuel caused it to be fortified; but in 1536 it was captured by Muley (Maulái) Ahmed al-Hasan. Its merchants were removed to Mogador in 1773. At the mouth of the Sús Leo places three little towns called Messa (Mássa), with a mosque popularly reputed the scene of Jonah's restoration to *terra firma*. The port of this name,[5] regularly visited by the Genoese traders in the 16th century, who exported skins, gum, wax, gold, and indigo, is no doubt at the mouth of the W. Mássa, 20 miles farther south.[6] Ifni, situated in 29° 23′ N. lat., and Sidi Worzek, the Cape Non[7] of the Portuguese, are the only points calling for notice till the better known Cape Nun is reached, which lies 5 or 6 miles north of the W. Der'a. With the Der'a the Sahara may be said to begin.

On most maps the interior of Morocco is represented as extremely mountainous; but, while it is traversed from east to west by more than one strongly-defined range, the greater part of the surface is really occupied by undulating steppe-like tracts diversified by low hills. The backbone of the country is the Great Atlas (Daran of the Berbers).[8] At its western extremity the range averages from 4000 to 5000 feet in height; after a slight falling off for a few miles it rises till it attains an elevation of 10,000 feet; beyond the pass (about 60 miles from the sea) which leads from Morocco to Tárúdant the summits seem to be between 11,000 and 11,500 feet; about 40 miles farther east there is a second pass at an altitude of about 7000 feet; and beyond that the main ridge continues 30 miles at a height of about 12,000 feet, with a few peaks reaching to 13,000 or 13,500 feet. Snow lies on some of the summits as late

1 The absurd story that about the 9th century it was an English possession has its root in the visits of the Normans to this quarter. The modern town sprang from a fortress built to protect the coast against them (Dozy, *Recherches*, 3d ed., ii. 264 *sq.*).

2 The Portuguese settlers, who had to leave it when Don José decided on surrendering this last stronghold of his country in Morocco, were afterwards sent to Brazil, where they founded Villa Nova de Mazagan.

3 *Bull. de la Soc. de Géogr.*, Paris, 1875.

4 This must not be confounded with Santa Cruz de Mar Pequeña, a post established in 1476 somewhere on this coast by Herrera, lord of the Canary Islands, and in modern times the subject of much geographical disputation. After obtaining permission to reoccupy the site the Spanish Government was unable to identify it.

5 See Valentin Ferdinand, *Beschreibung West Afrika's* (Mem. of the Acad. of Munich, 3d Class, pt. viii.).

6 Ya'kúbí, *Descr. al-Maghribi*, p. 126; *Hist. des Berbères*, ii. 279.

7 No, Non, Nor, Naum, Não, are among the various readings. It was another Cape Non to the south of Cape Bojador which seems to have given rise to the proverb, *Quem pasar o cabo de Não ou tornara ou não*. See *Bol. de la Soc. Geogr.*, p. 316, Madrid, 1880.

8 Pliny says the natives called the Atlas "Dyrin."

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al-Hodna were autonomous under a number of indigenous or foreign princes. The chief of these principalities were that of the Idrísites at Fez (*supra*, p. 581), the kingdom of Tahart, and that of Nákúr. In the first years of the 10th century the Fátimite caliphs, at the head of the powerful Berber tribe of Kotáma, overthrew the Aghlabites, thus putting an end for ever to Arab rule in North Africa, and rapidly extended their empire to the Atlantic. When the Fátimites established themselves in Egypt, the Zírid dynasty reigned as their vassals in the west, and maintained themselves with varying fortunes till the rise of the great empire of the Almoravides (*q.v.*), who yielded in turn to the Almohades (*q.v.*). The latter dynasty was extinguished by the princes of the Beni-Merín, whose chief, Ya'kúb b. 'Abd al-Hakk, captured Morocco in 1269 A.D. The subsequent history of Morocco and Fez under the Merinids and their successors presents little interest, being as full of internecine wars, contested successions, fratricides, general bloodshed, and barbarities as it is empty of all indications of an advance in civilization. As regards the relations of the country to European nations, four periods may be distinguished—(1) a period lasting down to the close of the 14th century, when the Moorish potentates were still the most prominent representatives of aggressive Mohammedanism; (2) a period during which the Portuguese and Spaniards, having expelled their invaders, made vigorous reprisals and obtained possession of many towns on the coast of Morocco; (3) a period in which these nations, disheartened by the disastrous defeat in the Battle of the Three Kings (1579), allowed the Moors to recover much of the ground they had lost, and to become, by their piracies and defiance of international law, an object if not of terror yet of apprehension and irritation; and (4) a period in which the prestige of this afterglow of greatness has gradually died out.

The following are the more noteworthy events in the Moorish annals since the beginning of the 15th century.

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The most distinguished member of the house of Morosini was Francesco, the captain-general of the republic against the Turks and conqueror of the Morea. He was born in 1618. In 1666 he was in command during an unfortunate campaign in Candia. In 1687 he conquered Patras, and so opened the Morea to the Venetian arms. In the following year he was elected doge. After his return to Venice the republic suffered severely in Candia, and though now an old man Francesco took the field again in 1693, but died the next year at Nauplia, seventy-six years of age. A more detailed account of his exploits will be found in the article VENICE.

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MORPETH, a municipal and parliamentary borough of Northumberland, England, is situated in a fine valley on the Wansbeck, and on the North-Eastern Railway, 50 miles south of Berwick and 16 north of Newcastle. The Wansbeck, which is crossed by a stone and two wooden bridges, winds round the town on the west, south, and east, and a small rivulet, the Cottingburn, bounds it on the north. Morpeth is irregularly built, but possesses a number of good shops. The parish church of the Blessed Virgin, a plain building of the 14th century, is situated on Kirk Hill, a short distance from the town. Among the other public buildings are the Edward VI.'s grammar school, reopened in 1857 after a Chancery suit lasting 150 years; the tow hall, erected in 1870 to supersede a building of 1714 Vanbrugh; and the county-hall and former gaol, in baronial style, built in 1814. Nothing remains of the o castle except the gateway. Morpeth had at one time one the largest cattle-markets in England. The industries the town include tanning, brewing, malting, iron and bra founding, and the manufacture of flannels, agricultr implements, and bricks and tiles. The population of municipal borough (231 acres) in 1871 was 4517, and 1881 it was 4556. The population of the parliamenta borough (17,085 acres) in the same years was 30,239 a 33,459.

Morpeth (*Morepath*, *i.e.*, the path over the moor) had attain some size before the Norman Conquest, when it was granted William de Merlay. From the De Merlays it passed through Greystocks and Dacres to the Howards, earls of Carlisle. So after the Conquest it obtained the privilege of a market, in 1552 arms were granted to it by Edward VI. It is a boron by prescription, and was incorporated by Charles II. By Municipal Act of 1835 the government was placed in a mayor a burgesses, but there is a local board of health distinct from corporation, having control over an area slightly larger than of the municipal borough. From 1553 the borough sent members to parliament, but since 1832 only one member has be returned, and in 1868 the area of the borough was increased.

MORPHEUS is a personification, apparently invent by Ovid (*Metam.*, xi. 635), of the power that calls shapes before the fancy of a dreamer. The name (f μορφή) expresses this function; Ovid translates it *artif simulatorque figuræ.* Morpheus is naturally represent as the son of Sleep (Somnus).

MORPHIA. See OPIUM.

MORPHOLOGY

THE term Morphology (μορφή, *form*), introduced by Goethe to denote the study of the unity of type in organic form (for which the Linnæan term METAMORPHOSIS (*q.v.*) had formerly been employed), now usually covers the entire science of organic form, and will be employed in this more comprehensive sense in the present article.

§ 1. *Historical Outline.*—If we disregard such vague likenesses as those expressed in the popular classifications of plants by size into herbs, shrubs, and trees, or of terrestrial animals by habit into beasts and creeping things, the history of morphology commences with Aristotle. Founder of comparative anatomy and taxonomy, he established eight great divisions (to which are appended certain minor groups)—*Viviparous Quadrupeds*, *Birds*, *Oviparous Quadrupeds and Apoda*, *Fishes*, *Malakia*, *Malacostraca*, *Entoma*, and *Ostracodermata*—distinguishing the first four groups as *Enaima* ("with blood") from the remaining four as *Anaima* ("bloodless"). In these two divisions we recognize the Vertebrata and Invertebrata of Lamarck, while the eight groups are identical with the Mammals, Birds, Reptiles, Fishes, the Cephalopods, Crustaceans, other Articulates, and Testaceans of recent zoology. Far, too, from committing the mistake often attributed to him of reckoning Bats as Birds, or Cetaceans as Fishes, he discerned the true affinities of both, and erected the latter into a special γένος beside the Viviparous Quadrupeds, far more on account of their absence of limbs than of their aquatic habit. Not only is his method inductive, and, as in modern systems, his groups natural, *i.e.*, founded on the aggregate of known characters, but he foreshadows such generalizations as those of the correlation of organs, and of the progress of development from a general to a special form, long afterwards established by Cuvier and Von Baer respectively. In the correspondence he suggests between the scales of Fishes and the feathers of Birds, in that hinted at between the fins of Fishes and the lim of Quadrupeds, the idea of homology too is nascent; from the compilation of his disciple Nicolaus of Dama who regards leaves as imperfectly-developed fruits, he see almost to have anticipated the idea of the metamorpho of plants. In short, we find a knowledge of struct facts and a comparative freedom from the errors in by physiological resemblance, of which his successors as Theophrastus and Pliny, generally mere classifiers habit, show little trace, and which the moderns have slowly regained. Little indeed can be recorded until t 13th century, when the reappearance of Aristotle's wo gave a new impulse to the study of organic nature. the works of this period that of Albertus Magnus is the most important; but they are all no more than vivals of Aristotle, marking the reappearance of scienti method and the reawakening of interest in and sympath with nature. Meanwhile leech and apothecary, alche and witch, were accumulating considerable knowledge plants, which, after the invention of printing, bec collected and extended in the descriptive and well-illu trated folios of Gesner and his successors, Fuchs, L and others, as well as by the establishment of bo gardens and scientific academies, while, as Sachs exp it, "in the sharpest contrast to the naive empiricism of t German fathers of botany came their Italian contemp Cæsalpinus, as the thinker of the vegetable world." Bo made systematic efforts,—the Germans vaguely seeking t natural affinities in mere similarities of habit, the Ita with no inconsiderable success striving towards an in lectual basis of classification. Monographs on groups plants and animals frequently appeared, those of Belon Birds and Rondelet on Fishes being among the earliest; in the former of these (1555) we find a comparison of

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Authorities.—Barbaro, *Genealogie delle Famiglie Patrizie Venete*, MS., clas. vii. cod. dccccxxvii., in the Marcian Library, Venice; Cappellari, *Campidoglio Veneto*, MS., clas. vii. cod. xvii., in the same library; Romanin, *Storia documentata di Venezia*; Freschot, *La Nobiltà Veneta*; Cicogna, *Iscrizione Veneziane*.

MORPETH, a municipal and parliamentary borough of Northumberland, England, is situated in a fine valley on the Wansbeck, and on the North-Eastern Railway, 50 miles south of Berwick and 16 north of Newcastle. The Wansbeck, which is crossed by a stone and two wooden bridges, winds round the town on the west, south, and east, and a small rivulet, the Cottingburn, bounds it on the north. Morpeth is irregularly built, but possesses a number of good shops. The parish church of the Blessed Virgin, a plain building of the 14th century, is situated on Kirk Hill, a short distance from the town. Among the other public buildings are the Edward VI.'s grammar school, reopened in 1857 after a Chancery suit lasting 150 years; the tow hall, erected in 1870 to supersede a building of 1714 Vanbrugh; and the county-hall and former gaol, in baronial style, built in 1814. Nothing remains of the o castle except the gateway. Morpeth had at one time one the largest cattle-markets in England. The industries the town include tanning, brewing, malting, iron and bra founding, and the manufacture of flannels, agricultr implements, and bricks and tiles. The population of municipal borough (231 acres) in 1871 was 4517, and 1881 it was 4556. The population of the parliamenta borough (17,085 acres) in the same years was 30,239 a 33,459.

Morpeth (*Moorpath*, *i.e.*, the path over the moor) had attain some size before the Norman Conquest, when it was granted William de Merlay. From the De Merlays it passed through Greystocks and Dacres to the Howards, earls of Carlisle. So after the Conquest it obtained the privilege of a market, in 1552 arms were granted to it by Edward VI. It is a boron by prescription, and was incorporated by Charles II. By Municipal Act of 1835 the government was placed in a mayor a burgesses, but there is a local board of health distinct from corporation, having control over an area slightly larger than of the municipal borough. From 1553 the borough sent members to parliament, but since 1832 only one member has b returned, and in 1868 the area of the borough was increased.

MORPHEUS is a personification, apparently invent by Ovid (*Metam.*, xi. 635), of the power that calls shapes before the fancy of a dreamer. The name (f μορφή) expresses this function; Ovid translates it *artif. simulatorque figuræ*. Morpheus is naturally represent as the son of Sleep (Somnus).

MORPHIA. See OPIUM.

MORPHOLOGY

THE term Morphology (*μορφή, form*), introduced by Goethe to denote the study of the unity of type in organic form (for which the Linnæan term METAMORPHOSIS (*q.v.*) had formerly been employed), now usually covers the entire science of organic form, and will be employed in this more comprehensive sense in the present article.

§ 1. *Historical Outline.*—If we disregard such vague likenesses as those expressed in the popular classifications of plants by size into herbs, shrubs, and trees, or of terrestrial animals by habit into beasts and creeping things, the history of morphology commences with Aristotle. Founder of comparative anatomy and taxonomy, he established eight great divisions (to which are appended certain minor groups)—*Viviparous Quadrupeds, Birds; Oviparous Quadrupeds and Apoda, Fishes, Malakia, Malacostraca, Entoma*, and *Ostracodermata*—distinguishing the first four groups as *Enaima* ("with blood") from the remaining four as *Anaima* ("bloodless"). In these two divisions we recognize the Vertebrata and Invertebrata of Lamarck, while the eight groups are identical with the Mammals, Birds, Reptiles, Fishes, the Cephalopods, Crustaceans, other Articulates, and Testaceans of recent zoology. Far, too, from committing the mistake often attributed to him of reckoning Bats as Birds, or Cetaceans as Fishes, he discerned the true affinities of both, and erected the latter into a special γένος beside the Viviparous Quadrupeds, far more on account of their absence of limbs than of their aquatic habit. Not only is his method inductive, and, as in modern systems, his groups natural, *i.e.*, founded on the aggregate of known characters, but he foreshadows such generalizations as those of the correlation of organs, and of the progress of development from a general to a special form, long afterwards established by Cuvier and Von Baer respectively. In the correspondence he suggests between the scales of Fishes and the feathers of Birds, in that hinted at between the fins of Fishes and the lim of Quadrupeds, the idea of homology too is nascent; from the compilation of his disciple Nicolaus of Dama who regards leaves as imperfectly-developed fruits, he se almost to have anticipated the idea of the metamorpho of plants. In short, we find a knowledge of struct facts and a comparative freedom from the errors in by physiological resemblance, of which his successors s as Theophrastus and Pliny, generally mere classifiers habit, show little trace, and which the moderns have slowly regained. Little indeed can be recorded until t 13th century, when the reappearance of Aristotle's wo gave a new impulse to the study of organic nature. the works of this period that of Albertus Magnus is the most important; but they are all no more than vivals of Aristotle, marking the reappearance of scienti method and the reawakening of interest in and sympath with nature. Meanwhile leech and apothecary, alch and witch, were accumulating considerable knowledge plants, which, after the invention of printing, bee collected and extended in the descriptive and well-illu trated folios of Gesner and his successors, Fuchs, Lo and others, as well as by the establishment of bot gardens and scientific academies, while, as Sachs exp it, "in the sharpest contrast to the naive empiricism of t German fathers of botany came their Italian contemp Cæsalpinus, as the thinker of the vegetable world." bo made systematic efforts,—the Germans vaguely seeking natural affinities in mere similarities of habit, the Ita with no inconsiderable success striving towards an in lectual basis of classification. Monographs on groups plants and animals frequently appeared, those of Belon Birds and Rondelet on Fishes being among the earliest; in the former of these (1555) we find a comparison of

plants, as well as of at least the higher animals, have been studied with much and ever-increasing accuracy of detail. (See ANATOMY, HISTOLOGY, EMBRYOLOGY.) Both vegetable and animal tissues have been simply classified both according to their adult forms and according to the embryonic layers from which they respectively arise. This scrutiny of plant and animal structure over and above the special generalizations of the botanist and the zoologist has afforded much result to general histology. The improvement of technical methods has of late years largely aided the progress of discovery. A return from the study of the cell-aggregate to that of the cell has commenced, and the question of cell-structure may be said to be again paramount in histology. The process of transverse division has of late been much elucidated, and, although its complex details cannot here be entered upon, the result has been to establish a minute and thorough correspondence in cases so widely dissimilar as pollen-grains from a flower-bud, the epidermis of a tadpole, or the cells of a tumour—a result which obviously enhances the morphological completeness of the cell theory. Minor modes of cell-multiplication also are not without their morphological interest. Gemmation, familiar in the yeast plant, occurs in other low and simple organisms, and may probably be identified with the formation of polar vesicles in ova as a modification of transverse division. Schleiden had supposed all new cells to originate within pre-existing cells, and this process, known as free-cell-formation, may really be observed in various plant and animal tissues. The protoplasm groups itself round new nuclei, the new cells being in fact formed much as Schwann had in his turn supposed; but these nuclei have repeatedly been shown to arise from segmentation of the original nucleus, and thus this process too seems a mere modification of the general one of transverse division. Conjugation, too—that coalescence of two similar cells which may be observed in many Algæ, Fungi, and Protozoa—is to be considered as the undifferentiated form of that fertilization which occurs in higher animals and plants, the two apparently similar masses having become respectively differentiated into ovum and spermatozoon, or into egg-cell and antherozoid. An indefinite number of amœboid cells sometimes flow together into a single mass,—a phenomenon regarded by some as multiple-conjugation, or perhaps more probably as an almost mechanical coalescence of exhausted cells, from which conjugation proper and finally fertilization may indeed have originated. The amœboid cells of higher animals similarly unite when drawn, and this formation of *plasmodia*, as these are termed, seems to be a deep-seated property of the amœboid cell. Similarly, too, the process of rejuvenescence which occurs in many of the lowest plants and animals, such as Protococcus and Amœba, where the protoplasm passes from a resting and encysted to a naked and mobile stage, has many analogues not only among the Protista but even in the tissues of higher animals, while the phases which the lowest organisms more or less exhibit—the encysted, the ciliated, the amœboid, and the plasmodial—may be regarded as the fundamental forms of a "life-cycle," fully represented indeed only in such extremely low organisms as Protomyxa and Myxomycetes, yet nowhere completely suppressed. The very highest plants and animals may thus be considered as aggregates of more or less differentiated and variously arranged encysted, amœboid, and ciliated cells, while their development and subsequent changes, their variations normal and pathological, in reality exhibit phases more or less distinct of the ancestral life-cycle.

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§ 4. *Individuality.*—Probably no subject in the whole range of biology has been more extensively discussed than that of the nature of organic individuality. The history of the controversy is of interest, since besides leading up to solid results it serves, perhaps better than any other case, to illustrate the slow emergence of the natural sciences from the influence of scholastic thought. Starting from the obvious unity and indivisibleness of Man and other higher animals, and adopting some definition such as that of Mirbel (exceptionally unmetaphysical, however), "Tout être organisé, complet dans ses parties, distinct et séparé des autres êtres, est un individu," it was attempted times without number to discover the same conception elsewhere in nature, or rather to impose it upon all other beings, plants and animals alike. The results of different inquirers were of course utterly discrepant. It seemed easy and natural to identify a tree or herb corresponding to the individual animal, yet difficulties at once arose. Many apparently distinct plants may arise from a common root, or a single plant may be decomposed into branches, twigs, shoots, buds, or even leaves, all often capable of separate existence. These, again, are decomposable into tissues and cells, the cells into nucleus, &c., and ultimately into protoplasmic molecules, these finally into atoms,—the inquiry thus passing outside organic nature altogether and meeting the old dispute as to the ultimate divisibility of matter. In short, as Haeckel remarks, scarcely any part of the plant can be named which has not been taken by some one for the individual. It is necessary, therefore, briefly to notice some of the principal works on the subject, and these may conveniently be taken in descending order.

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form higher aggregates which he terms *zoïdes*. Such zoïdes may be irregular, radiate, or linear aggregates, of which the two former classes especially are termed *dèmes*. The organ—Haeckel's idorgan—is excluded, since tissues and organs result from division of labour in the anatomical elements of the mérides, and so have only a secondary individuality, "carefully to be distinguished from the individuality of those parts whose direct grouping has formed the organism, and which live still, or have lived, isolated from one another." Perrier further points out that undifferentiated colonies are sessile, as Sponges and Corals, while a free state of existence is associated with the concentration and integration of the colony into an individual of a higher order.

So far the various theories of the subject; detailed criticism is impossible, but some synthesis and reconciliation must be attempted. Starting from the cell as the morphological unit, we find these forming homogeneous aggregates in some Protozoa and in the early development of the ovum. But integration into a whole, not merely aggregation into a mass, is essential to the idea of individuality; the earliest secondary unit, therefore, is the gastrula or méride. This stage is permanently represented by an unbranched Hydra or Sponge or by a Planarian. These secondary units may, however, form aggregates either irregular as in most Sponges, indefinitely branched as in the Hydroids and Actinozoa, or linear as in such Planarians as Catenula. Such aggregations, colonies, or demes, not being aggregated, do not fully reach individuality of the third order. This is attained, however, for the branched series by such forms as Siphonophores among Hydrozoa, or Renilla or Pennatula among Actinozoa; for linear aggregates again by the higher Worms, and still more fully by Arthropods and Vertebrates. Aggregates of a yet higher order may occur, though rarely. A longitudinally dividing Nais or laterally branched Syllis are obviously aggregates of these tertiary units, which, on Haeckel's view, become integrated in the Echinoderm, which would thus reach a complete individuality of the fourth order. A chain of Salpæ or a colony of Pyrosoma exhibits an approximation to the same rank, which is more nearly obtained by a radiate group of Botryllus around their central cloaca, while the entire colony of such an Ascidian would represent the individual of the fifth order in its incipient and unintegrated state,—these and the preceding intermediate forms being, of course, readily intelligible, and indeed, as Spencer has shown, inevitable on the theory of evolution.

The exclusion of tissues and organs from rank in this series is thus seen to necessarily follow. Ectoderm and endoderm cannot exist alone; they and the organs into which they differentiate arise merely, as Jäger expresses it, from that concentric lamination, or, with Perrier, from that polymorphism of the members of the colony, which is associated with organic and social existence. The idea of the antimere is omitted, as being essentially a promorphological conception (for a Medusoid or a Star-fish, though of widely distinct order of individuality, are equally so divisible); that of the metamere is convenient to denote the secondary units of a linear tertiary individual; the term persona, however, seems unlikely to survive, not only on account of its inseparable psychological connotations, but because it has been somewhat vaguely applied alike to aggregates of the second and third order; and the term colony, corm, or deme may indifferently be applied to those aggregates of primary, secondary, tertiary, or quaternary order which are not, however, integrated into a whole, and do not reach the full individuality of the next higher order. The term zooid is also objectionable as involving the idea of individualized organs, a view natural while the medusoid gonophores of a Hydrozoon were looked at as evolved of its homologue in Hydra, whereas the latter is really a degenerate form of the former. Passing to the vegetable world, here as before the cell is the unit of the first order, while aggregates representing almost every stage in the insensible evolution of a secondary unit are far more abundant than among animals. Complete unity of the second order can hardly be allowed to the thallus, which Spencer proposes to compound and integrate into tertiary aggregates—the higher plants; as in animals the embryological method is preferable, both as avoiding gratuitous hypothesis and as leading to direct results. Such a unit is clearly presented by the embryo of higher plants in which the cell-aggregate is at once differentiated into parts and integrated into a whole. Such an embryo possesses axis and appendages as when fully developed (fig. 2). The latter, however, being as organs mere lateral expansions of the concentric layers into which the plant embryo, like the animal, is differentiated, and so neither stages of evolution nor capable of separate existence, are not entitled to individual rank. The embryo, the bud, shoot, or uni-axial plant, all thus belong to the second order of individuality, like the Hydroid they resemble. Like the lower Cœlenterates, too, aggregates of such axes are formed by branching out from their low degree of integration. Such colonies can hardly be termed individuals of the third, much less of higher order, at least without somewhat abandoning that unity of treatment of plants and animals without which philosophical biology disappears. Individuality of the second order is most fully reached by the flower,—the most highly differentiated and integrated form of axes and appendages. Such a simple inflorescence as a raceme or umbel approximates to unity of the third order, to which a composite flower-head must be admitted to have attained, while a compound inflorescence is on the way to a yet higher stage.

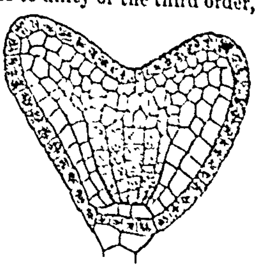

Fig. 2.—Embryo of Dicotyledon (after Sachs), showing incipient axis and appendages, as also the three concentric embryonic layers.

If, as seems probable, a nomenclature be indispensable for clear expression, it may be simply arranged in conformity with this view. Starting from the unit of the first order, the plastid or *monad*, and terming any undifferentiated aggregate a *deme*, we have a *monad-deme* integrating into a secondary unit or *dyad*, this rising through *dyad-demes* into a *triad*, this forming *triad-demes*, and these when differentiated becoming *tetrads*, the Botryllus-colony with which the evolution of compound individuality terminates being a *tetrad-deme*. The separate living form, whether monad, dyad, triad, or tetrad, requires also some distinguishing name, for which *persona* will probably ultimately be found most appropriate, since such usage is most in harmony with its inevitable physiological and psychological connotations, while the genealogical individual of Gallesio and Huxley, common also to all the categories, may be designated with Haeckel the *ovum-product* or *ovum-cycle*, the complete series of forms needed to represent the species being the *species-cycle* (though this coincides with the former save in cases where the sexes are separate, or polymorphism occurs). For such a peculiar case as *Diplozoon paradoxum*, where two separate forms of the same species coalesce, and still more for such heterogeneous individuality as that of a Lichen, where a composite unit arises from the union of two altogether distinct forms—Fungus and Alga,—yet additional categories and terms are required.[1]

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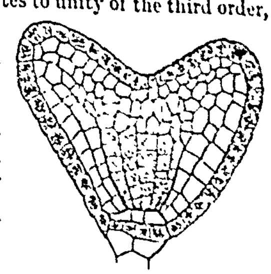
form higher aggregates which he terms *zoïdes*. Such zoides may be irregular, radiate, or linear aggregates, of which the two former classes especially are termed *dèmes*. The organ—Haeckel's idorgan—is excluded, since tissues and organs result from division of labour in the anatomical elements of the mérides, and so have only a secondary individuality, "carefully to be distinguished from the individuality of those parts whose direct grouping has formed the organism, and which live still, or have lived, isolated from one another." Perrier further points out that undifferentiated colonies are sessile, as Sponges and Corals, while a free state of existence is associated with the concentration and integration of the colony into an individual of a higher order.

So far the various theories of the subject; detailed criticism is impossible, but some synthesis and reconciliation must be attempted. Starting from the cell as the morphological unit, we find these forming homogeneous aggregates in some Protozoa and in the early development of the ovum. But integration into a whole, not merely aggregation into a mass, is essential to the idea of individuality; the earliest secondary unit, therefore, is the gastrula or méride. This stage is permanently represented by an unbranched Hydra or Sponge or by a Planarian. These secondary units may, however, form aggregates either irregular as in most Sponges, indefinitely branched as in the Hydroids and Actinozoa, or linear as in such Planarians as Catenula. Such aggregations, colonies, or demes, not being aggregated, do not fully reach individuality of the third order. This is attained, however, for the branched series by such forms as Siphonophores among Hydrozoa, or Renilla or Pennatula among Actinozoa; for linear aggregates again by the higher Worms, and still more fully by Arthropods and Vertebrates. Aggregates of a yet higher order may occur, though rarely. A longitudinally dividing Nais or laterally branched Syllis are obviously aggregates of these tertiary units, which, on Haeckel's view, become integrated in the Echinoderm, which would thus reach a complete individuality of the fourth order. A chain of Salpæ or a colony of Pyrosoma exhibits an approximation to the same rank, which is more nearly obtained by a radiate group of Botryllus around their central cloaca, while the entire colony of such an Ascidian would represent the individual of the fifth order in its incipient and unintegrated state,—these and the preceding intermediate forms being, of course, readily intelligible, and indeed, as Spencer has shown, inevitable on the theory of evolution.

The exclusion of tissues and organs from rank in this series is thus seen to necessarily follow. Ectoderm and endoderm cannot exist alone; they and the organs into which they differentiate arise merely, as Jäger expresses it, from that concentric lamination, or, with Perrier, from that polymorphism of the members of the colony, which is associated with organic and social existence. The idea of the antimere is omitted, as being essentially a promorphological conception (for a Medusoid or a Star-fish, though of widely distinct order of individuality, are equally so divisible); that of the metamere is convenient to denote the secondary units of a linear tertiary individual; the term persona, however, seems unlikely to survive, not only on account of its inseparable psychological connotations, but because it has been somewhat vaguely applied alike to aggregates of the second and third order; and the term colony, corm, or deme may indifferently be applied to those aggregates of primary, secondary, tertiary, or quaternary order which are not, however, integrated into a whole, and do not reach the full individuality of the next higher order. The term zooid is also objectionable as involving the idea of individualized organs, a view natural while the medusoid gonophores of a Hydrozoon were looked at as evolved of its homologue in Hydra, whereas the latter is really a degenerate form of the former. Passing to the vegetable world, here as before the cell is the unit of the first order, while aggregates representing almost every stage in the insensible evolution of a secondary unit are far more abundant than among animals. Complete unity of the second order can hardly be allowed to the thallus, which Spencer proposes to compound and integrate into tertiary aggregates—the higher plants; as in animals the embryological method is preferable, both as avoiding gratuitous hypothesis and as leading to direct results. Such a unit is clearly presented by the embryo of higher plants in which the cell-aggregate is at once differentiated into parts and integrated into a whole. Such an embryo possesses axis and appendages as when fully developed (fig. 2). The latter, however, being as organs mere lateral expansions of the concentric layers into which the plant embryo, like the animal, is differentiated, and so neither stages of evolution nor capable of separate existence, are not entitled to individual rank. The embryo, the bud, shoot, or uni-axial plant, all thus belong to the second order of individuality, like the Hydroid they resemble. Like the lower Cœlenterates, too, aggregates of such axes are formed by branching out from their low degree of integration. Such colonies can hardly be termed individuals of the third, much less of higher order, at least without somewhat abandoning that unity of treatment of plants and animals without which philosophical biology disappears. Individuality of the second order is most fully reached by the flower,—the most highly differentiated and integrated form of axes and appendages. Such a simple inflorescence as a raceme or umbel approximates to unity of the third order, to which a composite flower-head must be admitted to have attained, while a compound inflorescence is on the way to a yet higher stage.



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§ 9. *Relation of Morphology to Physiology.*—Although the pure morphologist investigates laws of structure only, and rightly eliminates the conceptions of life, environment, and function, yet if kept permanently apart from physiological considerations his labours would be incomplete and his results inexplicable, if not indeed almost illusory. For, however deeply one penetrates through superficial and adaptive characters to an apparently permanent and fundamental morphological type, this is itself but an earlier adaptation, showing the fading traces of an earlier adaptation still. And, conversely, the most superficial of adaptive characters, if transmitted to numerous varying descendants, may attain high morphological importance. The morphological aspect of an organism is merely statical, and, like that of an eddy or a vortex-ring, becomes only truly intelligible when viewed in its dynamic aspect; and thus, though the demonstration of the structural unity of the organic world is in itself a great result, yet the desire of a deeper explanation of form as determined by function and environment is thereby rendered all the more pressing. An example may be taken from botany. Thus Airy beautifully explains the phenomena of phyllotaxis as *adaptations to bud-life*. Or again, in a common flower, say the Dead-nettle, all the details of form are indeed described by the systematist with equal minuteness (a proceeding which, except in so far as serving for specific identification, is of no further scientific value), but receive separate interpretation from the two distinct standpoints of the morphologist and physiologist. The latter, to whom form is important merely so far as explanatory of function, shows how the tough persistent calyx is protective against various dangers, how the corolla serves to lure the fertilizing bees, which find in its lip a landing stage and in each lateral process a hold-fast, while its hood at once protects the pollen against rain and determines the curvature of the stamens,—this curvature, as well as their didynamous arrangement, [illegible] position, and linearly arranged anther-lobes being all adaptati[illegible] through the medium of the bee's hairy back to meet the similarly placed stigma of another flower,—and so on. The morphologist, on the other hand, analyses the calyx into its five constituent [illegible], reduces the corolla to a regular pentamerous type, ascertains the position of the four stamens, and asserts the loss of a fifth [illegible] one, finds the ovary *to be primitively* two-celled, and thus [illegible] a schematic conception of a not archetypal but ancestral form. This ground-form itself, however, suggests a new train of considerations both morphological and physiological respecting the [illegible]

[1] For bibliography see Lankester, *Ann. Mag. Nat. Hist.*, 1870, [illegible] *Jena. Zeitschr.*, 1883.

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§ 9. *Relation of Morphology to Physiology.*—Although the pure morphologist investigates laws of structure only, and rightly eliminates the conceptions of life, environment, and function, yet if kept permanently apart from physiological considerations his labours would be incomplete and his results inexplicable, if not indeed almost illusory. For, however deeply one penetrates through superficial and adaptive characters to an apparently permanent and fundamental morphological type, this is itself but an earlier adaptation, showing the fading traces of an earlier adaptation still. And, conversely, the most superficial of adaptive characters, if transmitted to numerous varying descendants, may attain high morphological importance. The morphological aspect of an organism is merely statical, and, like that of an eddy or a vortex-ring, becomes only truly intelligible when viewed in its dynamic aspect; and thus, though the demonstration of the structural unity of the organic world is in itself a great result, yet the desire of a deeper explanation of form as determined by function and environment is thereby rendered all the more pressing. An example may be taken from botany. Thus Airy beautifully explains the phenomena of phyllotaxis as adaptations to bud-life. Or again, in a common flower, say the Dead-nettle, all the details of form are indeed described by the systematist with equal minuteness (a proceeding which, except in so far as serving for specific identification, is of no further scientific value), but receive separate interpretation from the two distinct standpoints of the morphologist and physiologist. The latter, to whom form is important merely so far as explanatory of function, shows how the tough persistent calyx is protective against various dangers, how the corolla serves to lure the fertilizing bees, which find in its lip a landing stage and in each lateral process a hold-fast, while its hood at once protects the pollen against rain and determines the curvature of the stamens,—this curvature, as well as their didynamous arrangement, position, and linearly arranged anther-lobes being all adaptations through the medium of the bee's hairy back to meet the similarly placed stigma of another flower,—and so on. The morphologist, on the other hand, analyses the calyx into its five constituent sepals, reduces the corolla to a regular pentamerous type, ascertains the position of the four stamens, and asserts the loss of a fifth posterior one, finds the ovary to be primitively two-celled, and thus reaches a schematic conception of a not archetypal but ancestral form. This ground-form itself, however, suggests a new train of considerations both morphological and physiological respecting the origin of

[1] For bibliography see Lankester, *Ann. Mag. Nat. Hist.*, [illegible] *Jena. Zeitschr.*, 1883.

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MORRISTOWN, a city of the United States, county seat of Morris county, New Jersey, lies on the Whippany river, 31 miles from New York by the Morris and Essex division of the Delaware, Lackawanna, and Western Railroad. It was twice the headquarters of the American army during the War of Independence, and Washington's residence, owned by the Washington Association, assisted by the State, is a half-mile to the east. On Whatnong mountain, 3 miles distant, stands the State insane asylum, usually called Morristown Asylum, a vast granite building 1243 feet long, erected in 1874-1875, and capable of accommodating 1000 patients. The population in 1880 was 5418.

MORSE, Samuel Finley Breese (1791-1872), artist and inventor, was born at the foot of Breed's Hill, Charlestown, Massachusetts, on 27th April 1791. His father was the Rev. Jedediah Morse, D.D., the author of Morse's *Geography*. At the age of fourteen Samuel Morse entered Yale College; under the instruction of Professors Day and Silliman he received the first impulse towards those electrical studies with which his name is mainly identified. In 1811 Morse, whose tastes during his early years led him more strongly towards art than towards science, became the pupil of Washington Allston, then the greatest of American artists, and accompanied his master to England, where he remained four years. His success at this period was considerable; but on his return to America in 1815 he failed to obtain commissions for historical paintings, and after working on portraits for two years at Charleston, S.C., he removed first to Washington and afterwards to Albany, finally settling in New York. In 1825 he laid the foundations of the National Academy of Design, and was elected its first president, an office which he filled until 1845. The year 1827 marks the revival of Morse's interest in electricity. It was at that time that he learned from Professor J. F. Dana of Columbia College the elementary facts of electromagnetism. As yet, however, he was devoted to his art, and in 1829 he again went to Europe to study the old masters.

The year of his return, 1832, may be said to close the period of his artistic, and to open that of his scientific life. On board the packet-ship "Sully," which sailed from Havre 1st October 1832, while discussing one day with his fellow-passengers the properties of the electromagnet, he was led to remark: "If the presence of electricity can be made visible in any part of the circuit, I see no reason why intelligence may not be transmitted by electricity." It was not a novel proposition, but the process of formulating it started in his mind a train of new and momentous ideas. The current of electricity, he knew, would pass instantaneously any distance along a wire; and if it were interrupted a spark would appear. It now occurred to him that the spark might represent a part of speech, either a letter or a number; the absence of the spark, another part; and the duration of its absence, or of the spark itself, a third, so that an alphabet might be easily formed, and words indicated. In a few days he had completed rough drafts of the necessary apparatus, which he displayed to his fellow-passengers.[1] During the twelve years that followed Morse was engaged in a painful struggle to perfect his invention and secure for it a proper presentation to the public. The refusal of the Government to commission him to paint one of the great historical pictures in the rotunda of the Capitol seemed to destroy all his old artistic ambition. In poverty he pursued his new enterprise, making his own models, moulds, and castings, denying himself the common necessaries of life and encountering embarrassments and delays of the most disheartening kind. It was not until 1836 that he completed any apparatus that would work, his original idea having been supplemented by his discovery in 1835 of the "relay," by means of which the electric current might be reinforced or renewed where it became weak through distance from its source. Finally, on 2d September 1837, the instrument was exhibited to a few friends at his room in the university building, New York, where a circuit of 1700 feet of copper wire had been set up, with such satisfactory results as to awaken the practical interest of the Messrs Vail, iron and brass workers in New Jersey, who thenceforth became associated with Morse in his undertaking. Morse's petition for a patent was dated 28th September 1837, and was soon followed by a petition to Congress for an appropriation to defray the expense of subjecting the telegraph to actual experiment over a length sufficient to establish its feasibility and demonstrate its value. The committee on commerce, to whom the petition was referred, reported favourably. Congress, however, adjourned without making the appropriation, and meanwhile Morse sailed for Europe to take out patents there. The trip was not a success. In England his application was refused, on the alleged ground that his invention had been already published; and, while he obtained a patent in France, it was subsequently appropriated by the French Government without compensation to himself. His negotiations also with Russia proved futile, and after a year's absence he returned to New York. On 23d February 1843 Congress passed the long-delayed appropriation, steps were at once taken to construct a telegraph from Baltimore to Washington, and on the 24th of May 1844 it was used for the first time. Morse's patents were already secured to him and his associates, and companies were soon formed for the erection of telegraph lines all over the United States. In the year 1847 Morse was compelled to defend his invention in the courts, and successfully vindicated his claim to be called the original inventor of the electromagnetic recording telegraph. Thenceforward Morse's life was spent in witnessing the growth of his enterprise and in gathering the honours which an appreciative public bestowed upon him. As years went by he received from the various foreign Governments their highest distinctions, while in 1858 the representatives of Austria, Belgium, France, the Netherlands, Piedmont, Russia, the Holy See, Sweden, Tuscany, and Turkey appropriated the sum of 400,000 francs in recognition of the use of his instruments in those countries. In the preparations for laying the first Atlantic cable he took an active part, though the attempt of 1857, in which he personally engaged, was not successful. He died 2d April

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An *equitable* mortgage is constituted simply by the deposit of title-deeds in security for money advanced. The enactment of the Statute of Frauds that no action shall be brought on "any contract or sale of lands," &c., or any interests in or concerning them unless the agreement be in writing and signed by the party to be charged, has been cited as incompatible with the recognition of equitable mortgages, but it is argued by Lord Abinger that the Act was never meant to affect such a transaction. The deeds which are the evidence of title could not be recovered in an action at law, and, if they were claimed in equity, the court would require the claimant to do equity by repaying the money borrowed on the deposit. Any subsequent legal mortgagee, having notice of the deposit, will be postponed to the equitable mortgagee, and when the legal mortgagee has not inquired as to the title-deeds the court will impute to him such knowledge as he would have acquired if he had made inquiry.

As to mortgages of personal property see PLEDGE.

United States.—In the United States there is great diversity in the extent to which equitable principles have been formally substituted for the rules of the common law in dealing with mortgages. Washburn (*Law of Real Property*, vol. ii.) arranges the States into three "pretty well-defined classes." In the first, the mortgage deed is held to create a seizin of and an estate in the premises, with all its common law incidents, to be enforced if need be by ejectment. In the second, the mortgagee's rights are limited to such as the rules of equity prescribe, and may not be enforced by a suit at law. In the third, the mortgagee's interest is not deemed an *estate* at all, but is here only to be enforced by the sale of the premises as a means of paying the debt. In the first class come Massachusetts, Maine, Connecticut, New Hampshire, Rhode Island, Vermont, Indiana, Missouri, North Carolina, Mississippi, Minnesota; in the second, Iowa, Illinois, Pennsylvania, Kentucky, Ohio, Wisconsin, and Texas; in the third, California, Georgia, and New York, to which may be added Oregon. (E. R.)

MORTIFICATION, a term used in surgery signifying a local death. Any cause which interferes with the blood-supply of a portion of the body will, if sufficiently prolonged or sufficiently severe, give rise to mortification. In some cases the death may be preceded by inflammation; in others, as in old people with diseased vessels, the part may die in consequence simply of insufficient blood-supply without any previous inflammation. The part is said to mortify; the process is termed gangrene; the dead part is called a slough. A severe injury may end in mortification. Extreme heat as in severe burns, or extreme cold as in frost-bite, may give rise to the condition. Those parts of the body farthest from the centre of the circulation are most liable to mortification. Frost-bite, for example, may attack the toes or fingers as well as those parts which are most exposed to the cold, more particularly the point of the nose or the ears. The part affected becomes pale, bloodless, cold, and insensible. The great point to attend to is to restore the circulation gradually, using gentle friction. If the person is brought before a fire, or if any hot applications are used, then a rapid reaction may issue in a severe inflammation, which may be followed by mortification. Chilblain is a mild form of frost-bite occurring in young people with sluggish circulations, very often caused by sitting down before a strong fire with cold feet; any one suffering from cold feet or hands should take plenty of exercise, and if after a return from a sharp walk the feet remain cold the heat should be restored by rubbing with a rough towel.

MORTMAIN, STATUTES OF. The object and effect of these enactments are treated in the articles CHARITY and CORPORATION (*q.v.*). The following is a list of the Mortmain Acts:—

9 Henry III. c. 36 (Magna Charta); 7 Edward I. st. 2, c. 1 (De Religiosis); 13 Edward I. c. 32; 13 Edward I. c. 41; 18 Edward I. st. 1, c. 3; 27 Edward I. st. 2; 34 Edward I. st. 3; 18 Edward III. st. 3, c. 3; 15 Richard II. c. 5; 21 Henry VIII. c. 6, s. 5; 23 Henry VIII. c. 10; 1 and 2 Philip and Mary, c. 8, s. 51; 35 Elizabeth, c. 4; 21 James I. c. 1; 13 and 14 Charles II. c. 6, s. 10; 29 Charles II. c. 8; 7 and 8 William III. c. 37; 9 George II. c. 36; 43 George III. c. 108; 9 George IV. c. 85; and 2 and 3 William IV. c. 115.

MORTON, JAMES DOUGLAS, fourth earl of (1530-1581), regent of Scotland, second son of Sir George Douglas of Pittendriech, was born at Dalkeith in 1530. Having married Elizabeth, daughter of the third earl of Morton, he through her succeeded in 1553 to the title and estates of his father-in-law. After the return of Queen Mary in 1561 he was chosen a privy councillor, and in 1563 he became lord high chancellor. Though his sympathies were Protestant, he took no part in the combination of Protestant barons in 1565, but he headed the armed force of 150 men who took possession of Holyrood Palace to effect the assassination of Rizzio, and it was to his house that the leading conspirators adjourned while a messenger was sent to obtain Mary's signature to the "bond of security." The queen, before complying with the request, escaped to Dunbar, and on her return to Edinburgh with an escort of 2000 men Morton and the other leaders fled to England. After her marriage with Bothwell, Morton returned, and with 600 men appeared before Borthwick Castle, where the queen, in dread of a rising, had taken refuge. He was present at the remarkable conference at Carberry Hill, and he also took an active part in obtaining the consent of the queen at Lochleven to an abdication. Thereupon he was reappointed lord high chancellor, and also succeeded Bothwell as lord high admiral. On the death of the earl of Mar he became regent (October 1572). Through his persistence in recovering the crown jewels from the countess of Argyll, widow of the earl of Moray, Morton awakened the bitter animosity of Argyll and Athole, who persuaded the young king James VI. to assume the government. Morton deemed it prudent to resign, and for a time retired to Lochleven, but shortly afterwards, with the assistance of his nephew, the earl of Mar, he obtained possession of Stirling Castle, where the king was residing, and thus for a time recovered his old influence. Suddenly, however, he was accused by James Stewart, earl of Arran, of having taken part in the murder of Darnley, the father of the king, and being tried by a jury of sixteen peers, most of whom were his enemies, was condemned to death and beheaded on 2d June 1581.

MORVEAU. See GUYTON DE MORVEAU.

MOSAIC (late Greek ψήφωσις, from ψῆφος, a small stone; also μουσεῖον, *i.e.*, refined, delicate work; hence the Latin *opus musivum*) is the fitting together of many, generally small, pieces of marble, opaque glass, coloured clays, or other substances, so as to form a pattern: the

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MORTON, JAMES DOUGLAS, fourth earl of (1530-1581), regent of Scotland, second son of Sir George Douglas of Pittendriech, was born at Dalkeith in 1530. Having married Elizabeth, daughter of the third earl of Morton, he through her succeeded in 1553 to the title and estates of his father-in-law. After the return of Queen Mary in 1561 he was chosen a privy councillor, and in 1563 he became lord high chancellor. Though his sympathies were Protestant, he took no part in the combination of Protestant barons in 1565, but he headed the armed force of 150 men who took possession of Holyrood Palace to effect the assassination of Rizzio, and it was to his house that the leading conspirators adjourned while a messenger was sent to obtain Mary's signature to the "bond of security." The queen, before complying with the request, escaped to Dunbar, and on her return to Edinburgh with an escort of 2000 men Morton and the other leaders fled to England. After her marriage with Bothwell, Morton returned, and with 600 men appeared before Borthwick Castle, where the queen, in dread of a rising, had taken refuge. He was present at the remarkable conference at Carberry Hill, and he also took an active part in obtaining the consent of the queen at Lochleven to an abdication. Thereupon he was reappointed lord high chancellor, and also succeeded Bothwell as lord high admiral. On the death of the earl of Mar he became regent (October 1572). Through his persistence in recovering the crown jewels from the countess of Argyll, widow of the earl of Moray, Morton awakened the bitter animosity of Argyll and Athole, who persuaded the young king James VI. to assume the government. Morton deemed it prudent to resign, and for a time retired to Lochleven, but shortly afterwards, with the assistance of his nephew, the earl of Mar, he obtained possession of Stirling Castle, where the king was residing, and thus for a time recovered his old influence. Suddenly, however, he was accused by James Stewart, earl of Arran, of having taken part in the murder of Darnley, the father of the king, and being tried by a jury of sixteen peers, most of whom were his enemies, was condemned to death and beheaded on 2d June 1581.

MORVEAU. See GUYTON DE MORVEAU.

MOSAIC (late Greek ψήφωσις, from ψῆφος, a small stone; also μουσεῖον, *i.e.*, refined, delicate work; hence the Latin *opus musivum*) is the fitting together of many, generally small, pieces of marble, opaque glass, coloured clays, or other substances, so as to form a pattern; the

concrete and cement were both set, the surface of the pavement was rubbed down and polished. This kind of mosaic was largely used for floors of hypocausts; the concrete bed was then supported on large tiles resting on numbers of short pillars.

If used for upper floors very strong joists were required, and both Pliny (xxxvi. 25) and Vitruvius (vii. 1) recommend a *double* layer of boards, one crossing the other, on which the concrete and cement bedding was to be laid.

The usual Roman pavement was made of pieces of marble, averaging from a half to a quarter of an inch square, but rather irregular in shape. A few other, but quite exceptional, kinds of mosaic pavements have been found, such as that at the Isola Farnese, 9 miles from Rome, made of tile-like slabs of green glass, and a fine "sectile" pavement on the Palatine Hill, made of various-shaped pieces of glass, in black, white, and deep yellow. In some cases—*e.g.*, in the "House of the Faun" at Pompeii—glass tesseræ in small quantities have been mixed with the marble ones, for the sake of greater brilliance of colour. Pompeii is especially rich in its mosaics both on floor and walls, almost every house having at least its vestibule paved in this way.

In addition to graceful flowing patterns and geometrical designs, picture-like subjects of great elaboration frequently occur: of these the most important is the large and minutely-executed scene of the battle of Issus, found in the "House of the Faun." It is of special value as being the chief classical historical picture still existing. It is a well-designed though somewhat crowded composition, representing the moment of Alexander's victorious charge against the cavalry of Darius. The expression of the faces and the characteristic dresses of the Greeks and Persians are represented with great skill (see fig. 2). The tesseræ, as was always the case in this sort of work, are not all the same size, the smallest (only about one-tenth of an inch square) being reserved for the faces, where greatest refinement of detail was required. This was a floor-mosaic, though generally these minutely-executed works were affixed to walls.

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Another interesting mosaic from the wall of a house at Pompeii, of extremely delicate work, is a rehearsal scene in a Greek theatre, where the choregus is instructing the actors: it is specially remarkable from its being signed as the work of Dioscorides of Samos. Other figure-subjects are not uncommon, such as various representations of the victory of Theseus over the Minotaur, others of Achilles in Scyros, many hunting scenes, and the like.

Throughout England, Germany, France, Spain, Asia Minor, and Northern Africa in no way have signs of Roman occupation been left so clearly and in so conspicuous a form as by the numerous large and generally well-preserved mosaic pavements which have at various times been discovered in all these countries. In many cases, long after all traces of the walls of the buildings have disappeared, owing to their being dug up and removed for building purposes, the mosaics still remain to testify of the artistic power and mechanical skill of the Roman colonists.

Few countries are richer than England in these remains; the great pavements of York, Woodchester, Cirencester, and many other places are as elaborate in design and as skilfully executed as any that now exist even in Rome itself. In whatever country these mosaics are found, their style and method of treatment are always much the same; the materials only of which the tesseræ are made vary according to the stone or marble supplied by each country. In England, for instance, limestone or chalk often takes the place of the white marble so common in Italian and North African mosaics; while, instead of red marble, a fine sort of burnt clay or red sandstone is generally used; other makeshifts had to be resorted to, and many of the Anglo-Roman mosaics are made entirely without marble. It is perhaps partly owing to the great wealth of Northern Africa in marbles of many colours and of varying shades that the finest of all Roman mosaics have been found in Algeria and Tunis, especially those

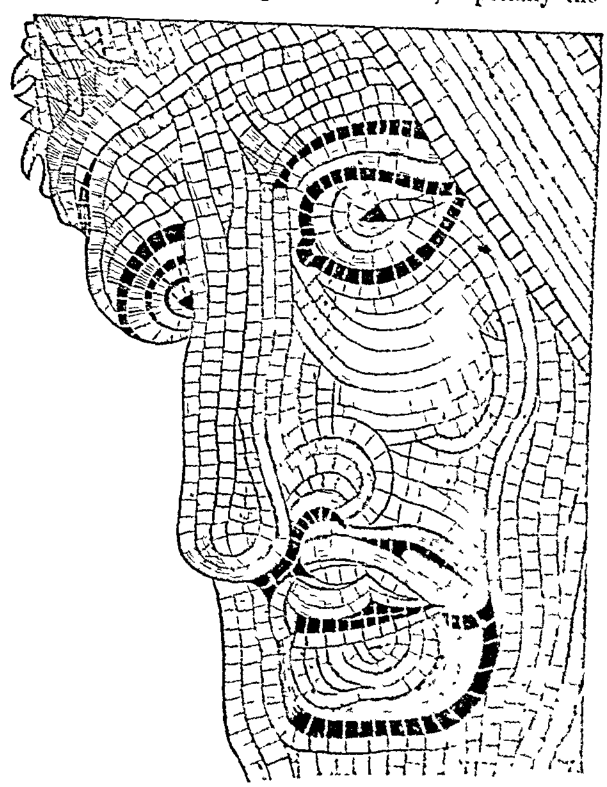

FIG. 2.—Part of a Persian's Head from the Battle of Issus, full size.

from Carthage, some of which have been brought to the British Museum. See *Archæologia*, vol. xxxviii. p. 202.

The range of colour in the marble tesseræ is very great, and is made use of with wonderful taste and skill: there are three or four different shades of red, and an equal number of yellows and greens, the last colour in all its tints being almost peculiar to this part of Africa, and one of the most pleasant and harmonious in almost any combination. Deep black, browns, and bluish-greys are also abundant. The white marble which forms the ground of nearly all the designs is often not pure white, but slightly striated with grey, giving great softness and beauty of texture to the surface, and doing away with too great monotony of tone. The Roman practice, common to all their mosaics, of not fitting the tesseræ quite closely together, but allowing the cement joints to show freely, was also of great value in giving effect to the general texture of the surface—a point quite forgotten by some later mosaic-workers, who thought that the closer their tesseræ were fitted together the better the mosaic would be. This remark does not apply to sectile mosaic, in which sufficient variety can be given by the markings and veins in each piece of marble. To return to the mosaics from Carthage, they are no less excellent in design than in the richness and beauty of their materials. Large size

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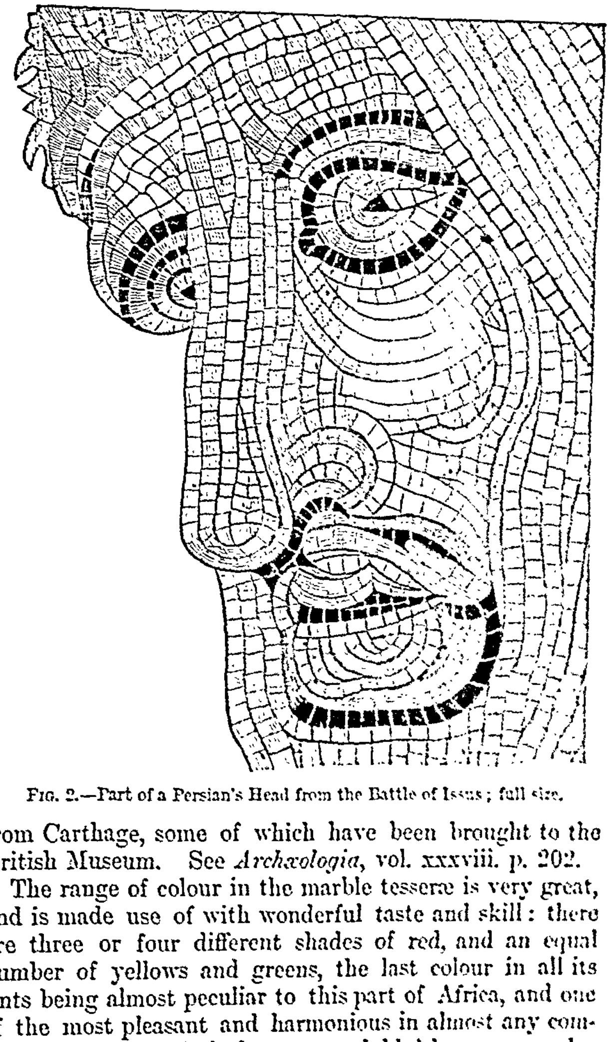

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The revival of the art of painting in Italy and the

Fig. 8.—Mosaic of Theodora and attendants, from S. Vitale, Ravenna; over life-size.

introduction of fresco work in the 14th century gave the deathblow to the true art of wall-mosaics. Though at first the simple and archaic style of Cimabue and his pupils Jacopo da Turrita, Giotto, and Taddeo Gaddi was equally applicable to painting or mosaic, yet soon the development of art into greater realism and complexity required a method of expression unfettered by the necessities and canons of mosaic-work. Pietro Cavallini, a Roman artist, was one of the last who worked according to the old traditions. His mosaic of the birth of the Virgin in S. Maria in Cosmedin, Rome, executed about the middle of the 14th century, is not without merit, though his superior knowledge of form has only caused his composition to be somewhat feeble and insipid compared with the works of the earlier artists. Even in the 15th century a few good mosaics were produced at Venice and elsewhere. Since then many large pictures have been copied in glass mosaic, generally attempts to imitate oil paintings, executed with great skill and wonderful patience, but all utterly worthless as works of art, merely costly monuments of human folly and misapplied labour. The mosaics from Titian's pictures on the west end of S. Mark's at Venice, Raphael's in the Chigi Chapel in S. Maria del Popolo, and many large pictures in S. Peter's in Rome, are the most striking examples of these.

The following list, in chronological order, comprises a selection from among the most important mediæval glass wall-mosaics during the period when mosaic-working was a real art:—

5th Century.

Ravenna.	Orthodox Baptistery—vault.
	Tomb of Galla Placidia—vault, 450
	Archbishop's Chapel—vault.
Rome.	S. Paolo fuori le mura—triumphal arch
	S. Maria Maggiore—square pictures over nave columns, and triumphal arch.
Milan.	S. Ambrogio, Chapel of S. Satiro—vault.
Fundi.	Cathedral—apse.
Nola.	Cathedral—apse.

6th Century.

Ravenna.	Arian Baptistery—vault
	S. Apollinare Nuovo—apse and nave, with 9th century additions
	S. Vitale—apse and whole sanctuary, *circa* 547.
	S. Apollinare in Classe—apse and nave, 549.
Rome.	SS. Cosmas and Damian—apse
Milan.	S. Lorenzo, Chapel of S. Aquilinus—vault.
Constantinople.	S. Sophia—walls and vault, *circa* 550
Thessalonica.	Church of St George—apse, &c., and S. Sophia—dome and apse
Trebizond.	S. Sophia—apse.

7th Century

Rome.	S. Agnese fuori le mura—apse, 626.
	S. Teodoro
Jerusalem.	"Dome of the Rock"—arches of ambulatory, 688.

8th Century.

Rome.	Baptistery of S. Giovanni in Laterano
	SS. Nereus and Achilles.
Jerusalem.	Mosque of Al Aksa—on dome.
Mount Sinai.	Chapel of the Transfiguration.

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	S. Marco—apse
	S. Maria della Navicella—apse, and "Chapel of the Column."
	S. Prassede—triumphal arch.
	S. Pudenziana, 884.
Milan.	S. Ambrogio—apse, 832.

10th Century.

Cordova.	Mihrab (sanctuary) of Mosque.

11th Century.

Jerusalem.	"Dome of the Rock"—base of cupola, 1027.
Constantinople.	Church of S. Saviour—walls and domes.

12th Century.

Venice.	S. Mark's—narthex, apse, and walls of nave and aisles.
Capua.	Cathedral—apse.
Torcello.	Cathedral—apse.
Murano.	Cathedral—apse.
Salerno.	Cathedral—apse.
Palermo.	Capella Palatina, begun 1132—the whole walls.
	Church of La Martorana—vault
Monreale.	Cathedral—the whole walls, 1170-90.
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Florence.	Baptistery vault, begun c. 1225 by Fra Jacopo.
	S. Miniato—apse and west front.
Rome.	S. Paolo fuori le mura—apse
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	S. Giovanni in Laterano—apse by Jacopo da Turrita, 1290
	S. Maria Maggiore—apse and west end by Jacopo da Turrita, 1292-1299, and Taddeo Gaddi.

[1] Unfortunately the world-wide fame of S. Mark's and the other great churches of Italy has subjected these extraordinary works to the fatal process of "restoration," and wherever any sign of decay in the cement backing (the tesseræ themselves are quite indestructible) has given the least excuse the "restorers" have destroyed whole masses of ancient work, and supplied its place with worthless modern copies. The mosaics of the S. Mark's baptistery, and of the apses at S. Miniato, at Pisa, and many other places have in this way been wantonly renewed within the last few years.

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AUTHORITIES.—*Classical Mosaics.*—Pliny, *H. N.*, xxxvi.; Vitruvius; Franks, *Slade Collection of Ancient Glass*, and *Excavations at Carthage*, 1860; Artaud, *Histoire de la peinture en mosaïque*, 1835; *Monumentos Arquitectonicos de España* ("Italica," "Cordoba," and "Elche"), 1859-83; Laborde, *Mosaïque d'Italica, près de Seville*, 1802; Ciampini, *Vetera Monumenta*, Rome, 1747; Von Minutoli, *Mosaikfussboden*, &c., 1835; Lysons, *Mosaics of Horkstow*, 1801, and *Roman Antiquities of Woodchester*, 1797; Mazois, *Les ruines de Pompéi*, Paris, 1812-38; *Real Museo Borbonico*, various dates; Roach Smith, *Roman London*, 1859; *Ausgrabungen zu Olympia*, 1877-82.

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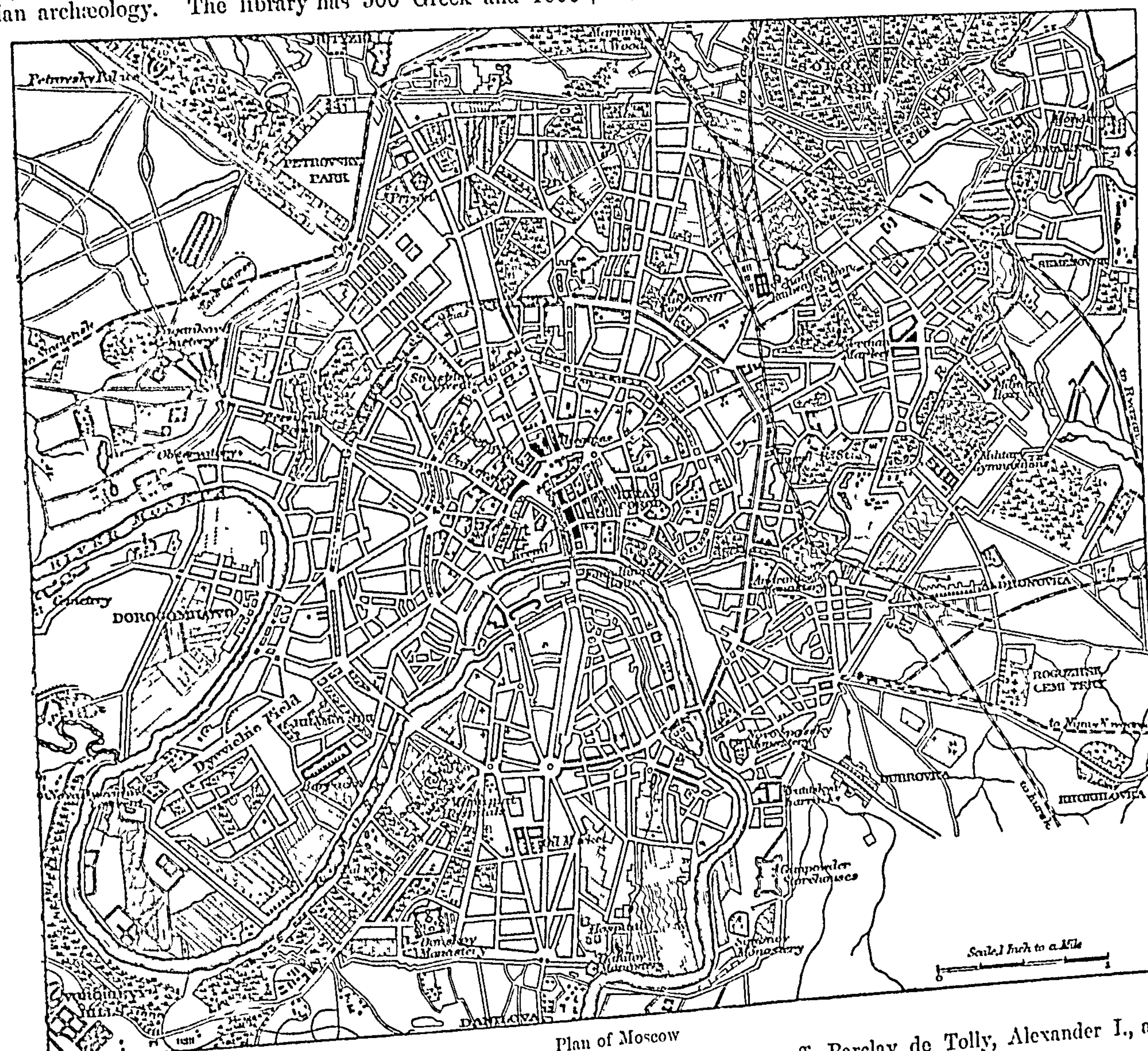

Plan of Moscow

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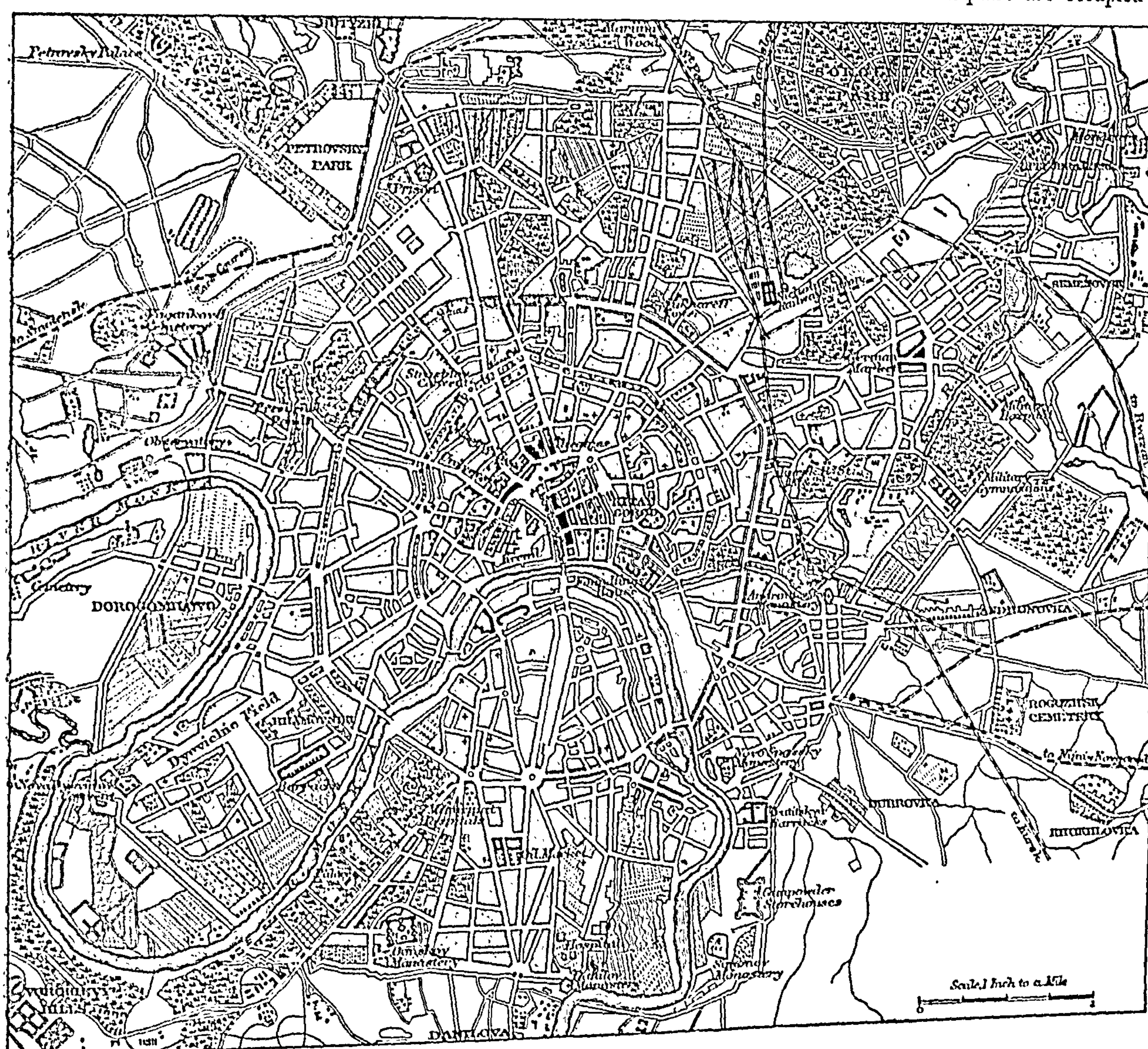

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still these are insufficient for the population, and the municipal schools every year refuse admission to about 1500 boys and girls.

The scientific societies are specially distinguished for their services in the exploration of the country. The following deserve particular mention:—the society of naturalists (founded in 1805); the society of Russian history and antiquities, which has published many remarkable works; the society of amateurs of Russian literature; the physical and medical society; the mathematical society; the society for the diffusion of useful books; the very active archæological society, founded in 1864; a society of gardening and of agriculture; several technical, artistic, and musical societies; and the very active young society of the friends of natural science, which already has published many useful volumes.

Among the museums of Moscow, the museum, formerly Rumantseff's, now connected with the so-called "public museum," occupies the first rank. It contains a library of 150,000 volumes and 2300 MSS., remarkable collections of old pictures, sculptures, and prints, as well as a rich mineralogical collection, and an ethnographical collection representing very accurately the various inhabitants of Russia. The historical museum has already been mentioned. The private museum of Prince Golitzyn contains a good collection of paintings and MSS.; and great treasures of archæology are amassed in various private collections in Moscow and its suburbs.

The periodical press does not on the whole exercise great influence; twenty-five periodicals are published, besides those of scientific societies. But Moscow publishes a far larger number of books for primary instruction and of the humblest kind of literature and prints for the use of peasants than any other Russian city.

The philanthropic institutions are numerous, the first rank being occupied by the immense Foundlings' Hospital, erected in 1764. The hospitals, municipal, military, and private, are very large, but much below the standard of other capitals. The number of private philanthropic institutions is very considerable.

Though the drama was introduced into Russia at Kieff, Moscow was the place of its development. The earliest stage representations were made at Moscow in 1640, and the first comedy—a translation of Molière's *Médecin Malgré Lui*—was played in the palace before Sophie, the sister of Peter I. It was only in 1759 that a theatre was erected. A large stone theatre was erected in 1776, and rebuilt in 1856 after a fire. It is for the Moscow stage that the best Russian dramas have been written, and it was in the "small theatre" that the best Russian actors—Schepkin, Sadovsky, Shumsky, and Madame Vasilieff—exhibited the comedies of Gogol, Griboyedoff, and Ostrovsky.

Moscow, where the Great-Russian language is spoken in its greatest purity, was the birthplace of the two chief Russian poets, Pushkin and Lermontoff, as well as of Griboyedoff, Ostrovsky, and Herzen. A monument to Pushkin was erected in 1880, on the Tverskoy boulevard. Griboyedoff, in his remarkable comedy *Goré ot uma*, has given a lively picture of the higher Moscow society of the beginning of this century, which continued to hold good until within the last few years. His remark as to the unmistakable individuality of the Moscow type also maintains its truth; although the physiognomy of Moscow has much changed since his day, it still has its special features that distinguish it from every other capital. The division of classes is much more felt at Moscow than elsewhere. The tendency towards originality, the love of grandiose undertakings, a kind of brag, together with little feeling of independence, a good deal of laziness, and much cordiality, still characterize the educated classes. The merchants live quite aloof from any political or even intellectual movement, under a rude patriarchal system, well described in the dramas of Ostrovsky. A large proportion of them are nonconformists. Their sons, the well-known kupecheskiye synki, "merchants' sons," when they leave this kind of life, astonish the capital with their extravagances and absurd display of wealth. But Moscow takes its present physiognomy chiefly from its busy lower classes. The streets are full of merchants and peasants, who continue to wear the old Russian garb, go on foot in the streets, drink tea in modest restaurants, and transact large business. From being a town of the aristocracy, Moscow is coming to be more and more a town of the wealthy middle classes, who persist in keeping the low educational level of the peasants in the villages, and have but one aspiration, to become in their turn "merchants" of the type described by Ostrovsky.

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still these are insufficient for the population, and the municipal schools every year refuse admission to about 1500 boys and girls.

The scientific societies are specially distinguished for their services in the exploration of the country. The following deserve particular mention:—the society of naturalists (founded in 1805); the society of Russian history and antiquities, which has published many remarkable works; the society of amateurs of Russian literature; the physical and medical society; the mathematical society; the society for the diffusion of useful books; the very active archæological society, founded in 1864; a society of gardening and of agriculture; several technical, artistic, and musical societies; and the very active young society of the friends of natural science, which already has published many useful volumes.

Among the museums of Moscow, the museum, formerly Rumantseff's, now connected with the so-called "public museum," occupies the first rank. It contains a library of 150,000 volumes and 2300 MSS., remarkable collections of old pictures, sculptures, and prints, as well as a rich mineralogical collection, and an ethnographical collection representing very accurately the various inhabitants of Russia. The historical museum has already been mentioned. The private museum of Prince Golitzyn contains a good collection of paintings and MSS.; and great treasures of archæology are amassed in various private collections in Moscow and its suburbs.

The periodical press does not on the whole exercise great influence; twenty-five periodicals are published, besides those of scientific societies. But Moscow publishes a far larger number of books for primary instruction and of the humblest kind of literature and prints for the use of peasants than any other Russian city.

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Such in brief *résumé* are the accounts of Moses given in the Bible[4] and the Midrash. In addition to these we have also the statements of Hellenistic writers, preserved chiefly in the *Contra Apionem* of Josephus. These are all of an Egyptian complexion, and probably embody no ancient and independent tradition, but, in all that relates to the Hebrews, where they do not rest upon pure conjecture, merely go back upon obscure rumours of Jewish origin and dress them up after the manner of the Midrash—only in a contrary sense, with hatred and not with love—and then seek to fit them as well as may be into the Egyptian history and chronology as known from other sources. The great number of new proper names of places and persons which occur in the writings of Manetho and his like cannot be urged against this view, for the Midrash also is full of them. The very name Osarsiph, given to Moses himself, moreover, suggests a suspicion of dependence on the Asaphsuph, "mixed multitude" of Numb. xi. 4 (comp. Exod. xii. 38); what is said in these places is known to have played a great part in the rise of the idle Egyptian tales about the origin of the Jews and of their lawgiver.

For literature, see the various commentaries on the Pentateuch, and especially Dillmann on Exodus. (J. WE.)

MOSES OF CHORENE was a native of Khor'ni[5] in Tarôn, a district of the Armenian province of Turuberan. According to the only trustworthy authority—the *History of Armenia*[6] which bears his name—he was a pupil of the two fathers of Armenian literature, the patriarch or catholicos Sahak the Great and the vartabed Mesrôb. Shortly after 431 he was sent by these men to Alexandria to study the Greek language and literature, and thus prepare himself for the task of translating Greek writings into Armenian. Moses took his journey by Edessa and the sacred places of Palestine. After finishing his studies in the Egyptian capital he set sail for Greece; but the ship was driven by contrary winds to Italy, and he seized the opportunity of paying a flying visit to Rome. He then visited Athens, and towards the end of winter (440) arrived in Constantinople, whence he set out on his homeward journey. On his arrival in Armenia he found that his patrons were both dead. The *History of Armenia* speaks of its author as an old, infirm man, constantly engaged in the work of translating.[7] In the later Armenian tradition

1 On the road occurred the remarkable incident which, in the view of the narrator, led to the circumcision of infants being substituted for that of the bridegroom (Exod. iv. 24, 25; ותגע לרגליו, to mark the substitution,—compare the euphemism in Isa. vii. 20).

2 Quite contrary to the sense of the Biblical narrative, Justin (xxxvi. 2, 13) says, "Sacra Ægyptiorum furto abstulit;" and still more perverse is the gloss which Ewald, proceeding upon this expression of Justin, gives.

3 The legend of his assumption is of later growth; see the apocryphal *Assumptio Moysis* (APOCALYPTIC LITERATURE, vol. ii. p. 177), and compare Luke ix. 30, 33; Jude 9.

4 Outside of the Hexateuch, however, he is almost never mentioned.

5 Cf. Sukias Somal, *Quadro della storia letteraria di Armenia*, p. 24 *sq.*

6 iii. 61 *sq.*, 68, 65.

7 On linguistic grounds, the Mechitarists ascribe to him the translation of Eusebius's *Chronicle* and of the Pseudo-Callisthenes.

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Such in brief *résumé* are the accounts of Moses given in the Bible[4] and the Midrash. In addition to these we have also the statements of Hellenistic writers, preserved chiefly in the *Contra Apionem* of Josephus. These are all of an Egyptian complexion, and probably embody no ancient and independent tradition, but, in all that relates to the Hebrews, where they do not rest upon pure conjecture, merely go back upon obscure rumours of Jewish origin and dress them up after the manner of the Midrash—only in a contrary sense, with hatred and not with love—and then seek to fit them as well as may be into the Egyptian history and chronology as known from other sources. The great number of new proper names of places and persons which occur in the writings of Manetho and his like cannot be urged against this view, for the Midrash also is full of them. The very name Osarsiph, given to Moses himself, moreover, suggests a suspicion of dependence on the Asaphsuph, "mixed multitude" of Numb. xi. 4 (comp. Exod. xii. 38); what is said in these places is known to have played a great part in the rise of the idle Egyptian tales about the origin of the Jews and of their lawgiver.

For literature, see the various commentaries on the Pentateuch, and especially Dillmann on Exodus. (J. WE.)

MOSES OF CHORENE was a native of Khor'ni[5] in Tarôn, a district of the Armenian province of Turuberan. According to the only trustworthy authority—the *History of Armenia*[6] which bears his name—he was a pupil of the two fathers of Armenian literature, the patriarch or catholicos Sahak the Great and the vartabed Mesrôb. Shortly after 431 he was sent by these men to Alexandria to study the Greek language and literature, and thus prepare himself for the task of translating Greek writings into Armenian. Moses took his journey by Edessa and the sacred places of Palestine. After finishing his studies in the Egyptian capital he set sail for Greece; but the ship was driven by contrary winds to Italy, and he seized the opportunity of paying a flying visit to Rome. He then visited Athens, and towards the end of winter (440) arrived in Constantinople, whence he set out on his homeward journey. On his arrival in Armenia he found that his patrons were both dead. The *History of Armenia* speaks of its author as an old, infirm man, constantly engaged in the work of translating.[7] In the later Armenian tradition

[1] On the road occurred the remarkable incident which, in the view of the narrator, led to the circumcision of infants being substituted for that of the bridegroom (Exod. iv. 24, 25; ותגע לרגליו, to mark the substitution,—compare the euphemism in Isa. vii. 20).

[2] Quite contrary to the sense of the Biblical narrative, Justin (xxxvi. 2, 13) says, "Sacra Ægyptiorum furto abstulit;" and still more perverse is the gloss which Ewald, proceeding upon this expression of Justin, gives.

[3] The legend of his assumption is of later growth; see the apocryphal *Assumptio Moysis* (APOCALYPTIC LITERATURE, vol. ii. p. 177), and compare Luke ix. 30, 33; Jude 9.

[4] Outside of the Hexateuch, however, he is almost never mentioned.

[5] Cf. Sukias Somal, *Quadro della storia letteraria di Armenia*, p. 24 *sq.*

[6] iii. 61 *sq.*, 68, 65.

[7] On linguistic grounds, the Mechitarists ascribe to him the translation of Eusebius's *Chronicle* and of the Pseudo-Callisthenes.

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Another extant work of Moses is a *Manual of Rhetoric*, in ten books, dedicated to his pupil Theodorus. It is drawn up after Greek models, in the taste of the rhetoric and sophistry of the later imperial period. The examples are taken from Hermogenes, Theon, Aphthonius, and Libanius; although the author is also acquainted with lost writings, *e.g.*, the *Peliades*, of Euripides. On account of the divergence of its style from that of the *History of Armenia*, Armenian scholars[3] have hesitated to ascribe the *Rhetoric* to Moses of Khor'ni; but, from what has been said above, this is rather to be regarded as a proof of its authenticity.

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and horse-shoe. Fig. 1 gives its plan as a good typical specimen of this normal type of mosque.

The mosque at Kairawán, Tunis, said to have been founded by 'Okba (see *supra*, p. 567), follows the normal plan, with 439 fine antique marble columns, horse-shoe arches, some pointed and others round, and flat ceiling of dark wood, once magnificently painted. Its sanctuary is ten aisles deep by seventeen wide. In the centre of the court is a marble fountain over the sacred well, said to communicate with the spring Zemzem at Mecca. Its minaret, a rather later addition, is very massive and stately; it is square, in three stories, each battlemented, the walls battering considerably. The sanctuary is domed, and the *Miḥráb* is decorated with magnificent tiles. Adjoining the sanctuary is a small room for a library.

The other great mosque of Sidi-'Okba, built soon after his death in 682, and containing his tomb, is in Algeria near Biskra; it much resembles the Kairawán mosque, but is less splendid, some of the columns being not of marble but of baked clay decorated with painting.

The great mosque of Fez, about the same date, is also very large and magnificent, with *Mimbar* and *Miḥráb* richly ornamented with minute mosaics; it has also a fine inlaid and painted wood ceiling, and some elaborately-carved doors. It still possesses a fine library. (See Amici, *Journey to Fez*, 1878.)

The great mosque of Damascus was built on the site of a Christian basilica, erected by Theodosius in 395-408. From 636, when the Arabs conquered Damascus, until 708 this basilica was used jointly both by the Christians and the Moslems. The basilica was then pulled down, and the present mosque built by the caliph Walíd. It has the normal plan, and is 508 feet by 320 feet. Its sanctuary is only three aisles deep; it has a central dome on the south or Mecca side, and on the east and west a large porch. Samhúdí records that one of the conditions of peace concluded between the Byzantine emperor and Walíd was that the emperor should furnish a certain number of workers in mosaic for the decoration of the mosques at Mecca, Medina, Jerusalem, and Damascus.

The mosque of Aḥmed Ibn Ṭúlún, in Cairo, completed in 879, has the normal plan, with the exceptional addition of an outer court, or wide passage, running round three sides of the rectangle,—probably to cut it off completely from the noise of the surrounding streets. It is built of brick, coated with delicate reliefs in stucco, once enriched with painting. The *Miḥráb* has beautiful mosaics, and the *Mimbar* is a marvel of delicate carving and inlay. The pillars and arches are of brick enriched with elaborate stucco-work. It has a very remarkable minaret on the west side, with a spiral external staircase. The architect was a Copt, an Egyptian Christian. It is perhaps the earliest important building in which the pointed arch is largely used.

The mosque Al-Azhar, "The Splendid," was built in the centre of New Cairo about 970 and, though frequently restored, has in the main been little altered. It is on the normal plan, with ranges of pointed and slightly horse-shoe arches, supported on more than 400 fine antique columns of marble and porphyry, chiefly from Roman buildings. Among its later decorations are magnificent wall-coverings of the most beautiful Persian tiles. It has a special interest in being the chief university of the Moslem world, containing some thousands of students (*mujáwirín*), for whom certain parts of the mosque (*Riwáḳ*) are screened off, according to the country from which they come. Thus special parts are reserved for natives of the various provinces of Egypt, of Morocco, Syria, Arabia, India, Turkey, &c. Each student can, if he is too poor to hire lodgings, live, eat, and sleep in the mosque. Each has a large chest in which to keep his clothes and books; these are piled against the walls to a height of seven or eight feet. The students pay no fees, but the richer ones give presents to the lecturers, who sit on the matting in various parts of the sanctuary or cloister, while the students sit round each lecturer in a circle. The usual course of study lasts for three years, though some students remain for much longer. The chief of the lecturers, called the *Sheikh al-Azhar*, receives about £100 a year, the others little or nothing, as regular pay. The Koran, sacred and secular law, logic, poetry, and arithmetic, with some medicine and geography, are the chief subjects of study.

Of mosques which are not built on the normal plan the earliest and most important are the two in the Harám al-Sheríf (High Sanctuary) at Jerusalem (see vol. xiii. p. 642).

The Kubbet al-Ṣakhra (Dome of the Rock), popularly, but wrongly, called the "Mosque of Omar," is not, strictly speaking, a mosque at all. It belongs rather to the class of "shrines,"—generally small square, circular, or octagonal buildings erected over some sacred spot or tomb. It is a very beautiful building, with high central dome, and double ambulatory round it,—the outer wall being octagonal, and the dome, with the pillars that carry it, circular in plan. It is decorated in a very sumptuous way by inlay of rich marbles and very splendid glass mosaics. The outer wall and most of the internal mosaics are later than the dome itself. Its windows of mosaic-like stained glass are very beautiful, and are almost the only Moslem example of the use of lead "cames," instead of the bits of glass being fitted into marble or stucco tracery; this, as well as the glass wall-mosaics, was probably the work of Byzantine artificers.[1]

The mosque within the same enclosure, called Al-Aḳṣá, is entirely roofed, with many aisles and columns, having no open court, quite unlike the usual arrangement of a mosque.

The finest and largest group of mosques is at Cairo. Many of them are very complicated buildings, with no resemblance to the normal plan before described. In some cases a hospital, a school, a court of justice, a monastery, or very frequently a tomb, forms part of the building, and causes considerable modifications in its plan.

The finest of these is the mosque of the sultan Hasan, built between 1356 and 1359 (fig. 2), a good specimen of a mosque built in a crowded site with a wing for a tomb. In plan it is cruciform, the central part being open to the sky; the eastern arm of the cross is the sanctuary, and farther east is the stately domed tomb of the sultan himself. All four arms of the cross are vaulted in stone with a plain waggon vault. Its magnificent entrance on the north, with an enormously high arch, decorated with stalactite reliefs in stone, is set somewhat askew to follow the line of the old street. It has two minarets, one of great height and grandeur.

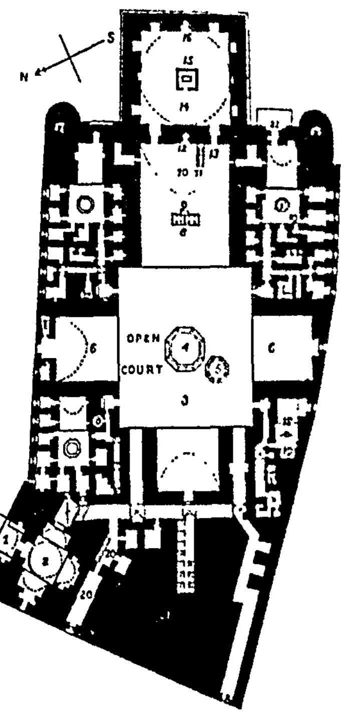

FIG. 2.—Plan of Mosque of Sultan Hasan, Cairo.

1, 2. Main entrance. 3. Court open to sky. 4, 5. Fountains. 6, 6. North and south vaulted transepts (the dotted lines show the curve of the vault). 8, 9. Dakka. 10. Sanctuary. 11. Mimbar. 12. Kibla. 13. Door to tomb. 14. Domed tomb-chamber. 15. Tomb within screen. 16. Kibla. 17, 17. Minarets. 18, 19, 20. Various entrances to mosque. 21. Small rooms connected with service of the mosque. 22. Sultan's private entrance.

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The most beautiful and graceful of all these mosques is that which contains the tomb of Sultan Káit-Bey, who died in 1496; its dome is entirely covered externally with beautiful and delicate reliefs carved in stone. Its minaret is a masterpiece of invention and extreme grace of outline, combined with the richest and most exquisite detail; like most of the Cairo mosques, its exterior is ornamented by bands of red stone alternating with the yellow Mokattam limestone. Inside, marble inlaid pavements and mosaics on the walls, with decorations in painted stucco and wood carved and inlaid give extreme splendour to the building. Fig. 3 gives its plan as a typical example of the combined mosque and tomb, —the latter the more important. The mosque inside the walls of

[1] See De Vogüé, *Temple de Jérusalem*, 18[illegible]; Texier, *Arch. Byzant.* [illegible]

and horse-shoe. Fig. 1 gives its plan as a good typical specimen of this normal type of mosque.

The mosque at Kairawán, Tunis, said to have been founded by 'Okba (see *supra*, p. 567), follows the normal plan, with 439 fine antique marble columns, horse-shoe arches, some pointed and others round, and flat ceiling of dark wood, once magnificently painted. Its sanctuary is ten aisles deep by seventeen wide. In the centre of the court is a marble fountain over the sacred well, said to communicate with the spring Zemzem at Mecca. Its minaret, a rather later addition, is very massive and stately; it is square, in three stories, each battlemented, the walls battering considerably. The sanctuary is domed, and the *Mihráb* is decorated with magnificent tiles. Adjoining the sanctuary is a small room for a library.

The other great mosque of Sidi-'Okba, built soon after his death in 682, and containing his tomb, is in Algeria near Biskra; it much resembles the Kairawán mosque, but is less splendid, some of the columns being not of marble but of baked clay decorated with painting.

The great mosque of Fez, about the same date, is also very large and magnificent, with *Mimbar* and *Mihráb* richly ornamented with minute mosaics; it has also a fine inlaid and painted wood ceiling, and some elaborately-carved doors. It still possesses a fine library. (See Amici, *Journey to Fez*, 1878.)

The great mosque of Damascus was built on the site of a Christian basilica, erected by Theodosius in 395-408. From 636, when the Arabs conquered Damascus, until 708 this basilica was used jointly both by the Christians and the Moslems. The basilica was then pulled down, and the present mosque built by the caliph Walíd. It has the normal plan, and is 508 feet by 320 feet. Its sanctuary is only three aisles deep; it has a central dome on the south or Mecca side, and on the east and west a large porch. Samhúdí records that one of the conditions of peace concluded between the Byzantine emperor and Walíd was that the emperor should furnish a certain number of workers in mosaic for the decoration of the mosques at Mecca, Medina, Jerusalem, and Damascus.

The mosque of Ahmed Ibn Túlún, in Cairo, completed in 879, has the normal plan, with the exceptional addition of an outer court, or wide passage, running round three sides of the rectangle,—probably to cut it off completely from the noise of the surrounding streets. It is built of brick, coated with delicate reliefs in stucco, once enriched with painting. The *Mihráb* has beautiful mosaics, and the *Mimbar* is a marvel of delicate carving and inlay. The pillars and arches are of brick enriched with elaborate stucco-work. It has a very remarkable minaret on the west side, with a spiral external staircase. The architect was a Copt, an Egyptian Christian. It is perhaps the earliest important building in which the pointed arch is largely used.

The mosque Al-Azhar, "The Splendid," was built in the centre of New Cairo about 970 and, though frequently restored, has in the main been little altered. It is on the normal plan, with ranges of pointed and slightly horse-shoe arches, supported on more than 400 fine antique columns of marble and porphyry, chiefly from Roman buildings. Among its later decorations are magnificent wall-coverings of the most beautiful Persian tiles. It has a special interest in being the chief university of the Moslem world, containing some thousands of students (*mujáwirín*), for whom certain parts of the mosque (*Riwák*) are screened off, according to the country from which they come. Thus special parts are reserved for natives of the various provinces of Egypt, of Morocco, Syria, Arabia, India, Turkey, &c. Each student can, if he is too poor to hire lodgings, live, eat, and sleep in the mosque. Each has a large chest in which to keep his clothes and books; these are piled against the walls to a height of seven or eight feet. The students pay no fees, but the richer ones give presents to the lecturers, who sit on the matting in various parts of the sanctuary or cloister, while the students sit round each lecturer in a circle. The usual course of study lasts for three years, though some students remain for much longer. The chief of the lecturers, called the *Sheikh al-Azhar*, receives about £100 a year, the others little or nothing, as regular pay. The Koran, sacred and secular law, logic, poetry, and arithmetic, with some medicine and geography, are the chief subjects of study.

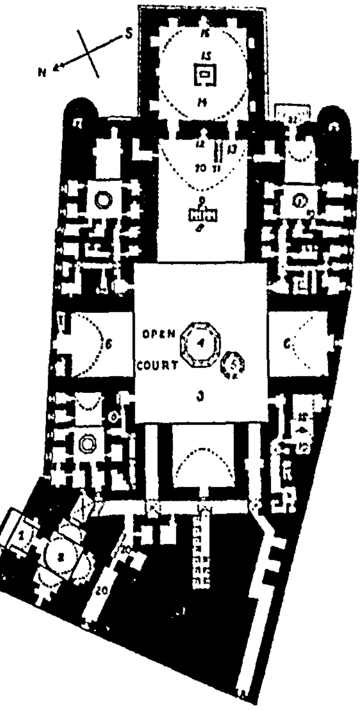
Of mosques which are not built on the normal plan the earliest and most important are the two in the Harám al-Sherîf (High Sanctuary) at Jerusalem (see vol. xiii. p. 642).

The Kubbet al-Sakhra (Dome of the Rock), popularly, but wrongly, called the "Mosque of Omar," is not, strictly speaking, a mosque at all. It belongs rather to the class of "shrines,"—generally small square, circular, or octagonal buildings erected over some sacred spot or tomb. It is a very beautiful building, with high central dome, and double ambulatory round it,—the outer wall being octagonal, and the dome, with the pillars that carry it, circular in plan. It is decorated in a very sumptuous way by inlay of rich marbles and very splendid glass mosaics. The outer wall and most of the internal mosaics are later than the dome itself. Its windows of mosaic-like stained glass are very beautiful, and are almost the only Moslem example of the use of lead "cames," instead of the bits of glass being fitted into marble or stucco tracery; this, as well as the glass wall-mosaics, was probably the work of Byzantine artificers.[1]

The mosque within the same enclosure, called Al-Aksá, is entirely roofed, with many aisles and columns, having no open court, quite unlike the usual arrangement of a mosque.

The finest and largest group of mosques is at Cairo. Many of them are very complicated buildings, with no resemblance to the normal plan before described. In some cases a hospital, a school, a court of justice, a monastery, or very frequently a tomb, forms part of the building, and causes considerable modifications in its plan.

The finest of these is the mosque of the sultan Hasan, built between 1356 and 1359 (fig. 2), a good specimen of a mosque built in a crowded site with a wing for a tomb. In plan it is cruciform, the central part being open to the sky; the eastern arm of the cross is the sanctuary, and farther east is the stately domed tomb of the sultan himself. All four arms of the cross are vaulted in stone with a plain waggon vault. Its magnificent entrance on the north, with an enormously high arch, decorated with stalactite reliefs in stone, is set somewhat askew to follow the line of the old street. It has two minarets, one of great height and grandeur.



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high latitudes they are driven off by anointing the body with fish-oil; and in hot climates "mosquito curtains" are part of the ordinary bed-furniture. It is only the female that bites; and, as it is but a very small proportion of them that can ever taste human blood or that of any warm-blooded animal, blood would not appear to be essential to their welfare. It has been suggested that warm blood may have an influence on the ova, but it cannot be supposed that the eggs of those multitudes of individuals that never get a chance to taste blood are necessarily infertile; everything tends to prove the opposite.

Of late mosquitoes have been accused of playing a hitherto unsuspected part in the dissemination of certain entozoic diseases. According to the researches of Drs Manson and Cobbold and others, it appears certain that the insects, in sucking the blood of persons who are hosts of the entozoon known as *Filaria sanguis-hominis*, take these parasites into their own system, and it is believed that they afterwards (by their death and otherwise) contaminate drinking water with them, and thus convey the entozoa into the blood of persons previously unaffected.

Mosquitoes are aquatic in their early stages. The female deposits her eggs in boat-shaped masses on the surface of the water. The larvæ are very active, and have a peculiar jerking motion; the last segment is furnished with a respiratory apparatus, the form of which probably varies according to the species, but it is usually a long tube, the extremity of which can be exposed to the external air. The pupæ are also active (contrary to the condition in most dipterous pupæ), and are odd-looking creatures owing to the great development of the thoracic region; the respiratory apparatus is in the thorax in this state, the extremity of the body having two swimming-plates; the pupæ do not eat, but their activity is very great.

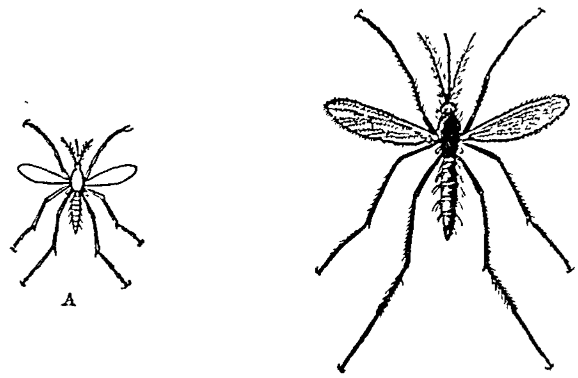

FIG. 1.—Mosquito (*Culex*). A, natural size; B, enlarged. (After Curtis.)

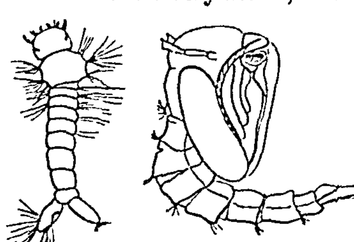

FIG. 2.—A, larva of *Culex*; B, pupa. (After Packard.)

No notice of the mosquito or gnat would be complete without an explanation of the mouth-parts by which it is enabled to cause such extreme irritation. When these parts are closed one upon the other the whole looks like a long proboscis; but in reality this consists of seven distinct slender pieces separated to the base, viz.—the labium, two maxillæ, two mandibles, the lingua, and the labrum. The nomenclature of the mouth-parts varies with different authors. G. Dimmock (*Anatomy of the Mouth-parts and of the Sucking-apparatus of some Diptera*), the latest investigator of this complex apparatus, states that the labium has for function, for the most part, the protection of the fine setæ which form the true piercing organ of *Culex*. In the female of *Culex* the protective sheath is formed by the labium alone. When the mosquito has found a place which suits it for piercing—for it often tries different places on our skin before deciding on one—it plants its labellæ firmly upon the spot, and a moment later the labium is seen to be flexing backwards in its middle; the setæ, firmly grouped together, remain straight and enter the skin. When the setæ have entered to nearly their full length, the labium is bent double beneath the body of the insect. When the mosquito wishes to withdraw the setæ it probably first withdraws the two barbed maxillæ beyond the other setæ, that is, so that their barbs or papillæ will be kept out of action by the mandibles and hypopharynx; then it readily withdraws the setæ, perhaps aiding their withdrawal by the muscles

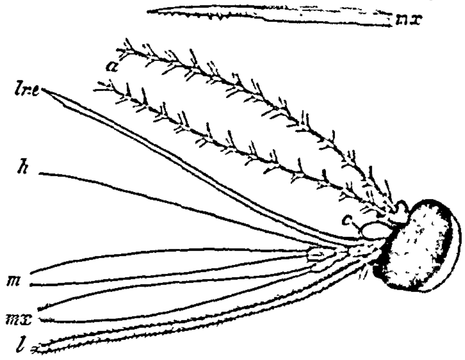

FIG. 3.—Mouth-parts, &c., of female *Culex* (after Dimmock). *a*, antennæ; *c*, clypeus; *h*, hypopharynx; *lr-e*, labrum-epipharynx; *l*, labium; *m*, mandibles; *mx*, maxillæ (with the tip of one of them enlarged).

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About 35 species of *Culex* (mosquito or gnat) have been described as inhabiting Europe, and about 130 from the rest of the world, but their differentiation is involved in great difficulty and uncertainty, and it is probable that the number of true species may be very much less. A species from Cuba has received the name *Culex mosquito*; but there is not one species that specially deserves the name more than another from a popular point of view, nor from a scientific point of view is there any difference between a mosquito and a gnat.

MOSQUITO COAST. See NICARAGUA.

MOSSES, or MUSCI, one of the two divisions of the botanical class *Muscineæ*, which includes also the Liverworts or *Hepaticæ*. See MUSCINEÆ.

MOSSLEY, a manufacturing town of Lancashire, England, is situated on the London and North-Western Railway and on the Huddersfield canal, near the west bank of the Tame, which here separates Lancashire from Cheshire, 3 miles north-east of Ashton-under-Lyne, and 10 east-north-east of Manchester. The houses are for the most part built of stone. To supersede the old church of St George, erected in 1757, a new building was begun in 1881. A mechanics' institute was erected in 1858. In the vicinity of the town is an eminence called Hartshead Pike, on which is a lofty circular tower surmounted by a spire rebuilt of stone in 1758. Mossley has risen into importance since the introduction of the cotton manufacture about fifty years ago. A fair is held annually. The town was placed under the Local Government Act in 1864, the district to which its provisions extend including also part of Saddleworth in Yorkshire. The total population was in 1871 10,578, and 13,372 in 1881.

MOSTAR, the chief town of Herzegovina, is built on both banks of the Narenta, about 35 miles from its mouth, and 40 miles south-west of Serajevo (Bosna Serai), the capital of Bosnia. Among the public buildings are a palace, two Greek churches, and forty mosques, in several cases with Roman or Byzantine tracery in their windows. The fine old bridge from which the town takes its name

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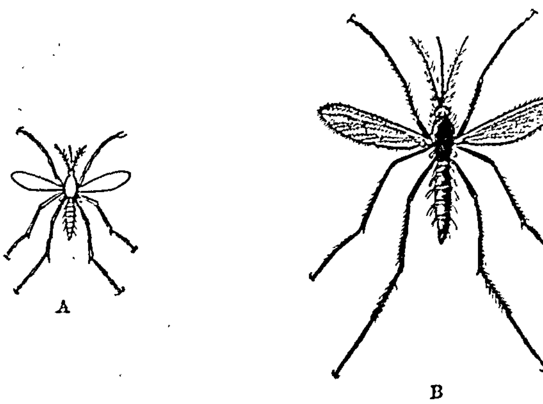

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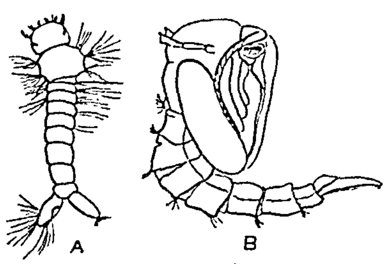

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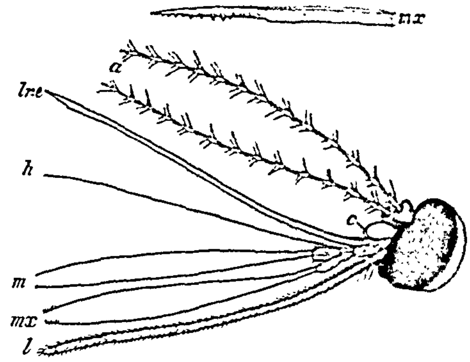

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